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ANNALS *of* SURGERY

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SURGICAL PROBLEMS IN THE RECONSTRUCTION OF PERIPHERAL NERVE INJURIES*

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LIEUTENANT COLONEL, M.C., U.S.A.

IN SO FAR as concerns the injured of the American Expeditionary Forces, the surgical treatment of peripheral nerve injuries did not begin, with few exceptions, until the soldier became a patient in one of the General Hospitals on this side of the Atlantic. That the management of peripheral nerve injuries was a problem distinct from other surgical problems was recognized by the Surgeon General by the following: Under his direction twelve hospitals were designated as peripheral nerve centres to which all patients with these lesions were ordered transferred from the ports of debarkation. To each of these centres was assigned an officer, experienced in neurological surgery, and a consulting neurologist, and for each, a uniform equipment for the examination and treatment of nerve injuries was provided. As further evidence of the importance of the peripheral nerve problem, the Surgeon General appointed a Consultant in neuro-surgery and a Peripheral Nerve Commission.

In order that the results of the examinations, the methods of recording the clinical findings, and the clinical records themselves should be as nearly uniform as possible, æsthesiometers were designed for the various centres with which to test sensory disturbances and to record them in terms of grammes, and a special Peripheral Nerve Register was prepared and distributed with instructions as to how the various clinical findings should be recorded. With this preparation, the Peripheral Nerve Commission will be provided with the records of all peripheral nerve cases, which, from the standpoint of uniformity and completeness, should be as nearly perfect as is possible under the widely variant conditions in the different hospitals. While many examinations by competent neurologists were made on the other side, with few exceptions none of the records accompanied the patient to his destination on this side.

Up to the present time it is estimated that there are over three thousand peripheral nerve cases in the peripheral nerve centres. Of this

* Read before the American Surgical Association, June 17, 1919.

number, the largest collection, 550, has been admitted to General Hospital No. 11, which has been my headquarters, and my remarks on the surgical treatment will be based on my experience with this group. Of this number up to date 275 have been discharged, as recovered, to convalescent centres, 75 have already begun to recover function spontaneously, 150 have been or will be operated upon, and the remainder are under observation.

At the Second Annual Meeting of the Inter-Allied Conference, held in London, May 20, 1918, Professor G. Verga presented a report of 1000 cases in which only 160, or 16 per cent., had been operated upon. Comparative statistics are not of much value, since there may be wide variation in the character of cases in different centres, but I should regard 25 to 30 per cent. as a reasonably conservative estimate of the proportion of cases in which operation is justifiable.

Only to those who have been burdened with the responsibility of conducting a peripheral nerve clinic will the magnitude and multiplicity of problems present themselves in their true proportion. The technic of examinations, the proper interpretation of the clinical findings, their proper evaluation, the decision for or against operation, the direction of treatment during the period of observation or recovery, apart from the difficulties of the operations themselves, these are all matters requiring time, experience and judgment.

It would not be possible in the allotted time even to mention many phases of scientific and practical interest, the peculiar sensory and motor phenomena in relation to partial and complete lesions and to recovery, the consideration of muscle tone and Tinel's sign, the trophic disturbances, the pathology of peripheral nerve lesions and the question of regeneration, so that I will restrict my discussion to those matters which relate solely to the surgical problems involved.

The first question for consideration is the time of operation. How long should one wait for evidence of spontaneous recovery? It has been my practice to wait at least until three months have elapsed from the date when the wound was healed, and in most instances, by observing this general rule, it is found that at least six months have passed since the injury was sustained. If at this time there are no signs of spontaneous recovery, on the one hand, and there is substantial evidence of a complete nerve interruption, whether or not this is interpreted as an anatomical division or a central neuroma, there are no grounds for further delay. One must not be deceived by the action of supplemental muscles which may compensate for the paralyzed muscle, as in one instance I recall when the ward surgeon reported to me six months after the injury that a patient with a complete median and ulnar paralysis could flex the wrist, and asked to have the operation postponed. An examination revealed the fact that the patient had learned how to flex the wrist with the short extensors of the thumb.

Assuming, however, that the wound heals promptly, as in wounds from machine-gun bullets, should an operation be advised, no matter how early, providing there is evidence of a complete nerve block? Captain Alexander, at the Alder Hey Military Hospital, Liverpool, maintained that cases sutured within four months of the injury do not do as well as those sutured after the sixth month, probably because degeneration was not complete in the peripheral segment. Whether this be true or not, the mere fact that many cases do not show signs of spontaneous degeneration until about the sixth month, is, I believe, sufficient justification for deferring the operation at least that long. I am quite aware of the fact that the results of primary suture are better than those of delayed suture, *ergo*, the sooner the operation, the better, but I also know that it is quite impossible to distinguish with absolute certainty by any single clinical sign or syndrome between a complete but transitory physiological block and a complete anatomical division. If the general dictum, as advocated by some, were observed, namely, to operate as soon as the wound permits, with evidence of complete physiological division, many a case would be explored which eventually would have recovered spontaneously, and resection and suture would not only have postponed the time of eventual recovery, but might have been totally unsuccessful.

As to matters purely technical, certain general principles should be observed. The tourniquet should not be used routinely, but in the exceptional case with massive cicatrization of the tissues, much time may be saved in the preliminary dissection if hemorrhage is controlled with a tourniquet. This should be removed before resection or suture; in the interval all bleeding is controlled. Liberal incisions are essential, as the nerve must be exposed and often liberated far above and below the lesion. Traumatism to the healthy portion of the nerve is to be avoided, and to this end I have found it advantageous to operate under a constant spray of saline solution, which keeps the field clear, and if sponging be necessary, use small, moist, cotton pledgets. The preliminary dissection is the most tedious of surgical procedures. It may be carried out with a small, sharp scalpel, or, as I prefer, when the nerve is embedded in scar tissue, with small curved eye tenotomy scissors and fine fixation forceps. Unless one begins well above and below the lesion, the identification of the different nerve trunks, from one another or from thrombosed vessels, particularly in the upper third of the arm, may be quite impossible. Only with continuous scrutiny will one avoid severance of important rami.

While the preliminary dissection or disentanglement of the lesion is tedious and time-consuming, it is the choice of procedure and the method of dealing with the lesion where experience and judgment count. This brings me to the consideration of the various operative procedures, neurolysis or liberation, resection and suture, and the various suggestions for dealing with large defects.

As the least complicated, neurolysis will first be considered. In proportion to the total number of operations, we have performed a neurolysis in 20 per cent. The figures correspond to the experience of other clinics, although in some, as in a series recorded by Verga, there were 80 neurolyses in 160 operations, or 50 per cent., and in the series of Delangiére (*Bull. et Mem. Soc. de Chir. de Paris,* 1918, xliv, 522) there were 113 liberations in 245 operations. It is not always easy to make a decision in favor of neurolysis as against suture. When there is a constricting band, with grooving of the nerve, or when there is compression and a narrowing of the lumen over a greater distance, when there is evident pressure from callus, a spicule of bone or aneurism, there admits of little doubt. Neurolysis is clearly indicated (and one should always give the nerve the benefit of the doubt) when it responds promptly to faradic stimulation. But in a number of cases, and I have often found this the case with the musculospiral, in addition to compression from external causes, there is an associated sclerosis or fibrosis of the nerve, which of itself may inhibit regeneration.

It has become almost a routine practice to recommend resection and suture in the presence of a spindle-shaped neuroma. However, bearing in mind clearly the pathology of the neuroma, it must be acknowledged that the neuroma *per se* is not an absolute barrier to the growth of neuraxes. It represents, to be sure, an effort by Nature towards regeneration against difficulties, but not always ineffectually. The development of a neuroma in cases undergoing spontaneous recovery is not uncommon, and it is not infrequent after suture or transplantation. Huber found in a neuroma, resected in this clinic from the sciatic nerve, such an active growth of neuraxes that he considered spontaneous recovery in this instance would not have been out of the question. If the presence of a neuroma cannot be the indisputable criterion, the final decision must rest upon the time which has elapsed between the injury and the operation and upon whether the nerve responds to faradism. The decision will in all cases be more or less arbitrary. If there are signs of total loss of function at the expiration of six months, resection and suture are justifiable. Joyce (*British Journal of Surgery,* vol. xx, No. 23, 1918) takes exception to this recommendation; the resection of a spindle-shaped neuroma is not justifiable, he says, unless failure has resulted from a neurolysis capsulectomy at which the thickened portion of the sheath has been removed. In this conclusion I cannot concur.

The technic of neurolysis should include the freedom of the nerve from the cause of compression, the cicatricial band or the more extensive scar tissue, dissecting the nerve free from the callus in which it is engaged, such as one often finds in musculospiral palsies. We sometimes find massive fibrous infiltrations of the sheath itself, and an attempt should be made to remove as much of this thickened portion of the sheath as possible, but not to the point of laying bare the fasciculi. In the reconstruc-

tion of the wound, the ideal and natural bed is an intermuscular plane or a plane between a muscle sheath and the deep fascia. To surround the nerve with flaps taken from adjacent muscles is not good surgery, since the reparative process in the healing of the muscle wound is attended with such cicatrization as of itself to threaten compression of the nerve. At least, this is the conclusion to which I have been led from observations I have made at secondary operations. I believe it entirely justifiable, too, in selected cases, and I refer to those of massive cicatrization in the arm, to transfer the nerve to a plane between the deep and superficial fascia; by this procedure the nerve is totally isolated from a field of connective tissue, which may inhibit the reparative process.

The great problem of peripheral nerve surgery is that involved in resection and the bridging of defects. The bringing into apposition of the divided segments with appropriate sutures is a matter of minor consideration if one observes certain accepted principles of nerve suture, but in gunshot wounds resection is a matter of necessity and to such an extent usually that approximation cannot be effected without resort to one method or another of bridging the defect. These methods now to be reviewed include posture, nerve stretching, nerve flaps, suture à distance, tubulization, lateral anastomosis, implantation-suture, transposition; some of these may, I think, be discarded with a few words, because, whatever evidence there may be from the experimental laboratory, the clinical evidence does not justify their adoption as acceptable procedures.

The so-called *flap-operation* as proposed by Letievant is not deserving of consideration, since, when the central and peripheral flaps are reflected, the ends of the respective flaps would not be in alignment and this would interfere with the down growth of neuraxes. The modification of this flap operation in which a flap is taken from a healthy nerve is objectionable chiefly because it involves sacrificing a portion of a normal nerve. The operation would be practicable only when two large trunks were in proximity, as in the upper arm. But one would hesitate in a case of ulnar paralysis, where the disability will often not affect deleteriously the patient's earning capacity, to sacrifice either the median or musculospiral.

As Huber says, *suture à distance* is more of academic than practical interest. In his laboratory experiments, success was attained in two out of three instances by interposing bundles of coarse catgut between the divided ends, but I know of no successful attempts in human surgery.

Tubulization, as a means of bridging defects, has been used extensively both in the laboratory and in the clinic, but there have been so many clinical failures that I have scrupulously avoided it. With Prussian pertinacity the Germans clung to this method in the early stages of the war. The so-called Edinger's tube, the formalized calf artery, was repeatedly employed, sometimes filled with blood serum, sometimes with agar-agar, but always, and I have seen the reports of 100 cases, with failure. Not only was there no evidence of regeneration, but on later

examination the gap had increased and bulbous formations were found on either end of the divided nerve.

In this connection a word may be said as to the use of protective sheaths both in neurolysis and nerve suture. I have refrained from any protection to the liberated or sutured nerve with fascia, fat, calf arteries or any other material, since there is every reason to believe that devitalized tissues, such as the foregoing, will stimulate connective tissue formation and thus militate against, rather than facilitate, nerve regeneration at the line of suture. A pedicle flap of muscle, fascia, or fat might overcome the objection to the use of these so-called protectives, but it has been my belief that the nerve sheath itself, if carefully approximated with sutures, offers adequate protection from the invasion of connective tissue.

Lateral anastomosis, as practiced by Hofmeister (*Beiträge zur Klin. Chir.,* 1915, 96, 329), has no merit whatsoever. In his report, which contained the notes of 24 operations, the results of the operations were not included. It is merely assumed that a neighboring healthy nerve serves as a favorable and convenient medium for the down-growth of neuraxes. If the terms lateral anastomosis and lateral implantation are synonymous, I quite agree with the wholesale condemnation this method has received; Tinel speaks of it as always useless and often mischievous; Moynihan, as to be sharply condemned, and Benisty, as illogical.

In order to avoid confusion, we must, I think, coin another term for an operation, similar to lateral anastomosis, in that the central or peripheral stump alone or combined are sutured into an adjacent nerve, but differing in this essential respect, namely, that a portion of this adjacent nerve is sacrificed. This is virtually a nerve suture and the term I would suggest as appropriate would be "implantation-suture."

I believe this operation has a field, limited though it may be, chiefly in the arm with large defects in the ulnar or musculospiral, not only because a healthy nerve is accessible, but because certain portions of the median may be sacrificed with only slight and transitory sensory loss. While on physiological and anatomical grounds I have regarded this so-called implantation-suture as justifiable in selected cases, I have not yet had a case in my clinic for which I thought it was appropriate. But looking over the literature, I found several instances in which it had been practiced with success. Thus in one of Joyce's cases, an ulnar lesion (*British Journal of Surgery,* January, 1919, p. 426), while almost one-third of the circumference of the median nerve had been sacrified, the sensory loss was entirely recovered in course of time, and in twenty-four months there was partial sensory and motor recovery in the ulnar area. Souttar (*British Journal of Surgery,* October, 1918) employed the method in two cases (Case 54 and Case 56); in one, he implanted the lower segment of the musculospiral nerve which was attached to the centre of the front of the median, the fibres of which were divided. Ten

months later there was faradic response in the extensors of the wrist. In the second case there was strong synergic action of the extensors of the wrist twelve months after the operation. It was noteworthy that Joyce cut the inner third of the median nerve and Souttar the external anterior fibres, and in both instances there was only transitory sensory disturbance.

On two occasions, one with a defect in two nerves, another with a defect in three, I have resected five centimetres of the humerus. This is a radical procedure and should be a court of last resort. When practiced, the operation should be divided into two stages, at the first liberating the nerves and resecting the humerus. This necessitates an incision on both the inner and outer aspects of the arm and after connecting the neuromata of the several nerves with strands of silk for later identification the wounds are closed, and the second stage is not undertaken until one is assured of uncomplicated wound repair. In one of the two cases, because of the time required at the first sitting in disentangling the injured nerves, the ulnar, median and internal cutaneous, the bone was not resected until a second sitting and the nerve finally sutured at a third.

The susceptibility of nerve trunks to stretching offers a valuable auxiliary measure for dealing with defects. Weir Mitchell in his classical monograph called attention to the tolerance of nerves to forcible stretching, and we know that, without the risk of rupturing its fibres, two to four centimetres of a defect may readily be made up. Nerve stretching with posture will often suffice to secure apposition in a defect of 7 to 8 cm. There are two ways of stretching the nerve. One as just described in the course of the operation, the other over a more extended period. The latter will be called for only in exceptional instances, and I do it in this way: If, after the nerve is liberated, it is evident that the defect cannot be bridged except with a graft, I pass heavy silk sutures through the bulbs and draw them as closely together as possible with the forearm or leg flexed. During the succeeding four weeks the limb is gradually brought into a position of extension and by this process the nerve is stretched. At a second operation, by bringing the limb again into flexion, approximation of the segments after resection is possible. This technic is particularly serviceable for injuries of the arm where two or more nerves are involved.

Nerve transposition as an aid to bridging defects is most helpful and is applicable to the ulnar and musculospiral, the former more frequently than the latter. The course of the musculospiral I have shortened by passing the peripheral segment between the biceps and brachial anticus and uniting it with the central segment on the inner aspect of the arm. The ulnar is isolated from its normal location and transposed to the flexor aspect of the forearm. I can see no advantage in following Stiles' recommendation to tunnel beneath the pronator radii teres and there are many disadvantages. In the first place, the deeper course is the longer when the forearm is in flexion, as it usually is when the nerve is sutured,

and secondly, the branches to the flexor carpi ulnaris and flexor profundus digitorum are sacrificed. These rami may both be conserved providing one slits them up as far as may be necessary beyond the point at which they join the parent trunk. Even though it may be more important to restore function to the intrinsic muscles of the hand, it need not be done at the expense of the ulnar flexor supply. The third situation in which transposition may be of service is the knee. Here in large defects of the external popliteal the distance from the bifurcation of the sciatic to the head of the fibula may be shortened by transposing the nerve to a plane superficial to the ham-string tendon with the limb in flexion.

With large defects advantage must unquestionably be taken of favorable positions to secure apposition without tension, such as flexion of the forearm or knee, adduction of the arm, inclination of the head toward the affected side.

As a last resort only should one resort to a transplant, not that there is not enough clinical evidence at hand to warrant the procedure, but the percentage of successful sutures is greater with direct suture than with the graft. In dealing with 150 nerve lesions at General Hospital No. 11, we have used a graft to repair the defect on seven occasions, as follows:

1 musculospiral	defect 7 cm.	Transplant; musculocutaneous (leg)
1 brachial plexus	defect 7 cm.	Transplant; musculocutaneous (leg)
1 ulnar	defect 5 cm.	Transplant; musculocutaneous (leg) Transplant; dorsal branch of ulnar
1 ulnar	defect 14 cm.	Transplant; musculocutaneous (leg)
1 external popliteal	defect 8 cm.	Transplant; musculocutaneous (leg)
1 median	defect 8 cm.	Transplant; musculocutaneous (leg)
1 brachial plexus	defect 5 cm.	Transplant; musculocutaneous (leg)

It is too soon to report ultimate results, but in two of the seven there is already evidence of regeneration. In a brachial plexus lesion the fifth cervical nerve was replaced with a transplant of 7 cm. from the musculocutaneous of the leg and already there is a faradic response in the deltoid muscle. In a second case, a 5 cm. defect from the level of the wrist and upwards, there is tingling on pressure over the graft, 3 cm. below the upper line of suture. In every instance an auto-graft has been used and usually the musculocutaneous, although according to one's convenience, the sural, the radial, or, with a defect in the nerves above the elbow, the internal cutaneous may be used. Two to four cables, according to the size of the nerve, should be used, and the sutures should be introduced in either end of the transplant at the proper interval before it is severed from its connection. According to Huber, whose investigations during the past two years have been most illuminating, the fascial cuff should not be used and we have observed this injunction. Huber believes the auto-transplant should always be given preference, but in a recent communication he writes that he has obtained favorable results with homo-transplants stored in vaseline and in liquid

petrolatum. In his experiments with homo-transplants, stored in 50 per cent. alcohol, the neuraxes have grown 3 cm. into the distal segment.

In reckoning how much of the nerve is to be resected, as many fasciculi as possible should be spared. By palpation, inspection, and with the clinical notes, one can determine whether the entire trunk or but a part need be sacrificed, but when in doubt electrical excitation is helpful, stimulating first the various aspects of the nerve through the sheath and, if still in doubt, after the sheath has been opened. By this means I have been able to conserve healthy fasciculi which otherwise would have been sacrificed.

For the ultimate success of suture, the most essential factor is the presence of healthy fasciculi, free from the grasp of cicatricial tissue. Granted this, the prognosis may be good in spite of a clumsy suture. One is always tempted to keep the defect within reasonable limits, fearing the difficulty in securing apposition. But if after the preliminary sections, distal and central, the cut section does not present healthy fasciculi without scar tissue, slice after slice should be removed until the desired picture is obtained. One soon learns to recognize these conditions; when, upon section, the ends of the fasciculi project a little beyond the cut surface, one is reasonably sure that the section has been made above and below the invasion of scar tissue. *Per contra,* if the cut section is smooth, and the fasciculi do not project, it is because they are engaged in scar tissue and a higher or lower level must be inspected. Successive sections should not be made at greater intervals than 2.5 mm., since at this distance the whole picture may change. I have found a safety-razor blade preferable to either a scalpel or ordinary razor blade. The sheath of the nerve must be grasped on either side to steady the nerve while the section is being made.

One tension suture of chromic catgut, through the entire thickness of the nerve, one centimetre from the free end, with four to eight epineural sutures of the finest silk, suffices to keep the sheath in apposition. The tension suture should not be tied until the epineural sutures are in place and then just fast enough to bring the fasciculi in contact; if too tight, the fasciculi will be crushed, if too loose, a blood clot may form in the interspace. Second in importance only to the necessity of securing a healthy segment for suture is the avoidance of undue tension. Every resource must be availed of to enable one to bring the segments into apposition without undue tension.

We have dealt in but fragmentary fashion with the problems of nerve reconstruction. There are many minor points in technic, as affecting individual nerves, that are deserving of consideration. Enough has been said, however, to emphasize the complexity of the problem and the important part played by judgment and experience. Nothing has been said of tendon transplantation for those cases in which nerve suture has failed or is difficult, or where spontaneous regeneration has been arrested. The

two situations in which tendon transplantation is particularly adaptable are (1) in the residual paralysis of the extensor longus digitorum, when the patient has recovered full power in all the muscles supplied by the musculospiral, with the exception of the common extensors to the fingers; and (2) in the residual paralysis of the anterior tibial with foot-drop. Tendon transplantation should be resorted to in both these lesions and no patient should be discharged until an attempt has been made in this way to supplement the paralyzed muscle.

The after-treatment is a matter of vital consideration; massage, galvanism and later faradism, properly selected exercises, these must be continued faithfully and persistently until voluntary movement has returned. Secondary operations in some instances will be inevitable.

The Surgeon General has given every consideration to this branch of reconstructive surgery. Within two months practically all cases requiring surgical treatment will have been operated upon. Recovery of function is a slow process and it remains to be determined how long after the operation the patients will be retained in government hospitals.

The final chapter of peripheral nerve surgery cannot be written until two years hence, at least, so far as concerns the wounded of the American forces. The final test of superiority claimed for one method or another must be based upon the end results. As one of the most important functions, it remains for the Peripheral Nerve Commission, acting under the direction of the Surgeon General, to follow up all cases that have or will be discharged from the General Hospitals and prepare a final report based upon the end results.

LYMPHOSARCOMA OF THE MESENTERY

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Solid tumors of the mesentery are not of frequent occurrence. In 1897 Harris and Herzog [1] collected 56 cases from the literature and added another one of their own. In 1899 Herzog [2] reported a lymphosarcoma arising in this region. In 1905 Bowers [3] described a mesenteric lipoma. This same year Vance [4] collected 28 cases from the literature of the preceding five years. Since then isolated cases have continued to appear in the literature so that now there are approximately 100 cases on record.

Lymphosarcoma is in itself not a common lesion. Symmers [5] reports that in the 5500 autopsies conducted at Bellevue Hospital during the last ten years only twelve instances of lymphosarcoma were encountered. In the fifty-seven mesenteric tumors collected by Harris and Herzog, there are possibly three lymphosarcomas, although only one is so listed. In Vance's collection, there are two specimens recorded as lymphosarcoma and one as a small round-celled sarcoma. Royster [6] reported in 1911 two cases of round-celled sarcoma of the mesocolon. It is possible that some of these tumors listed as round-celled sarcoma were actually of lymphoid origin. Occasionally lymphosarcoma of the mesenteric or retroperitoneal nodes has gained access to the literature by reason of some striking complication such as the production of chylous ascites. The following case in which there was found a lymphosarcoma of the mesentery would appear to be of sufficient interest to justify its publication.

Case I.—E. M., boy, aged six years, was brought to the hospital on the 19th of July, 1919, for a palpable, visible tumor of the abdomen, associated with recurrent attacks of abdominal "cramps." The family and previous history were negative. Nine weeks before examination the patient was kicked in the abdomen by his brother. A week later another injury was received in the same region by a fall over a baby carriage. From this time the patient had suffered with severe attacks of "cramps" in the abdomen, during which he doubled up with pain and broke out in a cold sweat. There was never any nausea or vomiting and nothing abnormal was noted in the urine or stools. At first these attacks occurred two or three times a week. Of late they have been more frequent, the abdomen has become noticeably enlarged and the child has become pale, weak, listless and does not care to play. There has been no cough or loss of appetite. There has been a progressive loss of weight.

Physical examination shows a thin, sallow-complexioned, poorly

nourished white boy apparently five years of age. The head, neck, heart, lungs, extremities, and external genitalia are normal. There is no œdema of the feet or ankles. There is evidence of recent wasting of the subcutaneous tissues. The abdomen is full, slightly protuberant and round in contour, except in the right lower quadrant, where a tumor is seen. There is no bulging in the flanks. The superficial veins are enlarged and quite prominent over the front and sides of the abdomen, the lower part of the front of the chest wall, and the upper parts of the thighs. The abdomen is thin walled, soft and generally tympanitic, except over the tumor mass in the right lower quadrant. The edge of the liver is felt at the costal margin. The spleen is not palpable. The presence of free fluid was not determined. The tumor filling the right lower quadrant is firm, elastic and irregular in outline. Its inner margin reaches the median line and its upper margin is above the level of the umbilicus. It is not attached to the abdominal wall and can be readily displaced laterally and to a less extent vertically. There is no tenderness upon manipulation. Temperature and pulse were normal. Examinations of the urine and stools were negative. Blood examination: Hæmoglobin, 90 per cent.; red cells, 4,000,000; white cells, 11,000; polymorphonuclears, 81 per cent.; lymphocytes, 17 per cent.; mononuclears, 7 per cent., and eosinophiles, 1 per cent.

Operation was refused and the child was removed from the hospital. The attacks of pain continued with progressive loss of weight and strength. The patient was readmitted for operation seven weeks later. The tumor had increased in size, extending nearly to the costal margin and for a distance of two fingers' breadths to the left of the median line. Percussion yielded a tympanitic note above and to the outer side of the tumor. No attempt was made to determine by inflation the relation of the large bowel.

The rapid growth of the mass with loss of weight and strength bespoke malignancy, and the age of the patient's sarcoma. The mobility of the tumor, pronounced at the first examination, the negative urinalyses, the situation mesial to the ascending colon seemed to deny a sarcoma of the kidney. Sarcoma of the small bowel was ruled out by the freedom from digestive symptoms during the period of over ten weeks since the presence of the tumor was noted. A diagnosis of retroperitoneal sarcoma was made.

Under ether anæsthesia, the abdomen was opened through a vertical right rectus incision extending from the costal margin nearly to Poupart's ligament. An irregular mass the size of a grape fruit presented. The ascending colon lay behind and to its outer side. A segment of small intestine passed diagonally from above downward and outward over the inner third of the tumor. There were no adhesions. An incision was made in the peritoneal covering of the tumor beginning an inch away from the intestinal loop passing over it with the intention of securing a section for microscopical examination. The overlying gut and the inner leaf of the peritoneum were readily stripped from the mass, however, and it was dissected

out with surprising ease, a portion of the peritoneal covering on its outer side coming away with it. Several vessels were tied and the large gap in the outer leaf of the mesentery was united with a continuous suture. The viability of the intestinal loop that overlay the tumor was questioned, but as the inner layer of the mesentery seemed to be intact, it was hoped that the blood supply, though damaged, would still be adequate. Resection of the intestine was therefore not attempted. This proved to be an unfortunate decision: the child died with symptoms of obstruction four days later, and autopsy revealed a gangrenous area involving the gut for a distance of about 6 cm. Resection of the intestine with anastomosis might, therefore, have resulted in an operative recovery, though the numerous small nodules remaining in the base of the mesentery would probably have determined a fatal issue ultimately.

Pathological Report: Surgical Path. 15436. The specimen is a roughly lobulated mass covered by a glistening membrane. It measures (after fixation) 14 × 10 × 8 cm. Upon section, the cut surface presents a very soft and cellular appearance. About one-third of the mass is hemorrhagic. This area is that next to the raw surface described on the outside of the mass. The mass appears to be limited by its coverings and gives the impression of having resulted from the fusion of several lymph-nodes.

Microscopically, the mass is composed of small round cells supported upon a delicate reticulum of connective tissue. The tumor cells are round and contain a nucleus which is relatively large and eccentrically placed. The nuclei contain rather coarse chromatic granules. The cytoplasm stains well with the hematoxylin. The cells resemble very closely the ordinary lymphocyte and serve to classify the tumor in the lymphoblastoma group. Its regional character and invasion of capsule characterize it as a lymphosarcoma. The growth is rich in poorly formed, thin-walled blood-vessels. These are closely surrounded but not invaded by the tumor cells. Certain areas show marked necrobiotic changes. The cells are swollen and their nuclei have become indistinct. In many areas there is a frank necrosis. Sections from the hemorrhagic areas show an abundance of free blood-cells mingled with the tumor cells.

Autopsy Notes No. 2625 (abstracted).—The peritoneal cavity presents fresh fibrinous adhesions which mat the intestines together. There is also a small amount of free yellowish fluid. The omentum is bound to and encloses a loop of the small intestine. The appendix is normal. In the ileum, 10 cm. above the ileocæcal valve, is a gangrenous area involving the gut for a distance of 6 cm. The liver is covered with a fibrinous exudate. Its cut surface is pale. The gall-bladder appears normal. The genito-urinary system is not worthy of note. The retroperitoneal nodes are slightly enlarged. The base of the mesentery is filled with a number of nodular masses, the largest of which is 3 cm. in diameter. Histologically, the structure of the nodes is lost and the whole node is packed with cells of the lymphoid series.

Discussion.—The mortality following operations for solid tumors of the mesentery with or without resection of the intestine is high. In a series of twenty-seven cases, collected by Vance, there were sixteen recoveries and eleven deaths—a mortality of 41 per cent. Seven of these tumors were sarcomata, and only one of the patients recovered. Unquestionably the mortality is higher in these instances in which the tumor

proves to be malignant than in the benign forms of fibroma and lipoma which make up the greater number of the reported cases. The surgical procedure, whether enucleation alone or combined with intestinal resection, cannot be determined until the tumor is exposed. Resection requires more time, adds to the operative risk, and should be avoided whenever possible. In those cases in which the tumor bulges the mesentery chiefly on one side and the overlying gut is consequently placed laterally, it may be possible to enucleate the growth without dangerous interference with the blood supply. If the overlying gut is more centrally placed, the tumor bulging both leaves of the mesentery equally, or if the gut is adherent to the growth at its wall and involved in the process, resection should be proceeded with at once. Successful cases where enterectomy was combined with the removal of a mesenteric sarcoma have been reported by Harris and Herzog, Sawyer, Mathews, and others. The length of the intestine removed has varied from one-half an inch to eight feet and two inches. That the question of resection is not necessarily determined by the size of the tumor is evidenced by the case cited by Bowers where a fibroma weighing thirty pounds was successfully enucleated.

The case presented here adds one to the few of mesenteric sarcoma and the long list of sarcomata in other regions where the onset of the symptoms and the development of a tumor have followed a definite history of trauma. What, if any, etiological significance this trauma may have had, we do not undertake to say. The growth made its appearance within the time limits set by Sand. It is, of course, possible that a careful examination given an injured region may disclose the presence of a previously existing tumor of which the patient was unaware; and it is conceivable, also, that an existent impalpable tumor might take on a more rapid growth following an injury to the part, thus becoming palpable. In this case, the patient suffered from abdominal "cramps" for several weeks before the "lump" was noticed.

There is nothing distinctive in the history of the subjective symptoms to suggest the diagnosis. Abdominal pain may be present and severe enough to suggest biliary, renal, or appendicular colic, or it may be entirely absent. There may be slight nausea and constipation, but, as a rule, the patient is free from gastric and intestinal disturbances—a helpful point in the differentiation from sarcoma originating in the intestine, where, according to Spease, nausea, vomiting, alternating periods of constipation and diarrhœa with abnormal findings in the stool are early and prominent symptoms.

Objectively the patient is weak, anæmic and has lost in weight recently. The abdomen harbors a tumor more or less centrally placed, nodular, and freely movable. This free mobility is the most important single sign. It is said that no other abdominal tumor possesses it to the same degree. If, in addition, the presence of a loop of intestine passing over the mass can be demonstrated, which cannot be displaced and maintains a fixed relationship to the tumor through several examinations, a presumptive

diagnosis of mesenteric tumor is warranted. The tumor is tense and elastic and is often regarded as a cyst. Several instances are on record where a trocar was introduced, after the growth was exposed by laparotomy, before its solid nature was recognized. Effort should be made to determine the relation of the large bowel to the growth. If the tumor develops in the mesentery of the small bowel, the ascending and descending colon will each be found in its respective loin, external to the mass while the transverse colon will lie above it. In the differential diagnosis confusion has existed with cysts of the ovary, pancreas, tumors of the liver, enlargements and displacements of the kidney, hydrops of the gall-bladder, and growths of the bowel itself. Because of their rarity these growths are little considered in the diagnosis of abdominal tumors. From a practical viewpoint, the important thing is the recognition of the presence of a tumor and its prompt removal.

Kundrat and Paltauf were the first to give clean-cut descriptions of lymphosarcoma and to distinguish it from other malignant tumors of the lymph-nodes. In 1907 MacCullum studied eight cases which corresponded to this group. So that there is now recognized a definite form of neoplasm arising in lymphoid tissue and composed of lymphoblastic cells which do not remain within the confines of the involved nodes but infiltrate the adjacent tissues. Distant metastasis is rare, but all of the nodes of the region may be more or less involved. These regional types of growths can be subdivided as follows:

1. Cervical, axillary and inguinal. 2. Thoracic: (*a*) thymic, (*b*) peribronchial. 3. Abdominal: (*a*) gastro-intestinal, (*b*) intestinal, (*c*) mesenteric, (*d*) retroperitoneal.

The case here reported conforms to the established picture of a regional lymphosarcoma. The character of the blood-vessels easily accounts for the hemorrhage and degeneration present. This is in contradistinction to the thoracic type in which the rarity of degeneration and softening has long been emphasized. The size of the mesenteric mass as compared with the involved retroperitoneal nodes leaves little doubt that the tumor arose in the mesentery.

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RECURRENT NEPHROLITHIASIS*

By Otis Floyd Lamson, M.D.
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It is rather surprising that this important subject of recurrent nephrolithiasis has received comparatively little attention both in the literature and in the research laboratories, and we have as yet no definite preventive methods for the recurrence of stones in the urinary channels.

Personally, I must confess that a very much smaller portion of my limited knowledge of kidney stones, primary or recurrent, I have gathered from the trying school of personal experience. While the larger part I have obtained from the thoughts and observations of men who possess not only the necessary mental capacity, but also the institutional opportunity for original research work.

To-day we are privileged to enjoy the hospitality of such distinguished men and their remarkable institution which has turned more than any other its enlightening searchlight on the various puzzling and annoying problems that cross the path of a practitioner of medicine and surgery.

In my professional activities I meet no patient with greater timidity than one that comes to me with a recurrent kidney stone. I am very timid when confronting such a patient and my words of ultimate result of the operation are indeed few and carefully selected. I am well aware that I am dealing with a disease whose true etiology is not definitely known, and the treatment, surgical or medical, or both, may and may not remove the cause of his peculiar kidney activity.

In order to give the patient with kidney stones as efficient treatment as possible his family history, mode of living, occupation, and his environment must be carefully studied. If the case be a recurrence the findings of the first operation and the chemical composition of the stones removed may throw some light on the obscure etiology of his trouble.

The general etiology of recurrent nephroliathiasis cannot differ materially from that of primary stones and it is therefore worth while for us to bear in mind the different causes of renal calculi that have been advanced at different times.

Unfortunately, we have as yet no definite etiology of this disease. We can only speak in general terms. Some attribute the formation of stone to some obscure chemical change in the composition of the urine; others emphasize the influence of microörganisms, of injury, and inflammatory diseases. I believe, as stated by Doctors White and Martin, that the formation of kidney calculi is due to the precipitation in the kidney tubules

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or pelvis of the solid constituents of the urine, this precipitation always taking place on an organic base, that may be mucus, epithelial cells, blood-clot, or colloid material. A coagulation necrosis of cells caused by interference with the circulation favors deposition of lime salts. All concrements, whether they be the size of a grain of sand or of a goose-egg, have a distinct albuminoid framework upon which the constituents of the urine are deposited.

Diathesis possesses a distinct influence upon stone formation which is commonly associated with the uric acid, the oxalate, or the phosphatic diathesis. Ebstein holds that the excess of urates, oxalates, or phosphates in the urine does not form stone by direct deposition in the excretory canals in the pelvis of the kidney, but that these ingredients favor a coagulation necrosis of cells, which furnishes the organic framework essential for such calculus formation; the same effect may be produced by local sepsis.

Those who advance chemical theories as causative agents speak of the influence of heredity, race, climate, diet, drinking water, drugs and intoxicants and faulty metabolism as contributing factors. Even incidences of gout and rheumatism have been held responsible for kidney stones. Against this theory an English army officer of considerable experience in the tropics speaks of the unusual prevalence of stone in the urinary tract among the inhabitants where gout or rheumatism is practically unknown. The cause of this prolific calculus formation he attributes to the native peculiar diet which is rich in albumin and phosphates and lacks the necessary quantity of salt, which is essential with a vegetable diet.

Against the theory that renal calculi are of bacterial origin, Cabot and Crabtree in a joint paper state that "the relation of infection to stone formation is not a factor of great importance, for were such the case, stone in the kidney would be far more common in the female than it is in the male, following the well-known fact that kidney infection is more common in women than in men." In one of my cases of recurrent kidney stones I was told that for several generations many male members of the family had had sometime or other some such kidney trouble—yet none of the female members had been affected. It is generally accepted that renal calculi are more common in men than in women.

A great many, like Albarran, consider primary stones to be of non-bacterial origin, but the secondary or recurrent types to be of bacterial origin. Ransohoff finds that primary stones consist of uric acid, urate of sodium and ammonium, oxalate of lime, carbonate of lime, and lastly of cystin of xanthin, which are deposited from the urine without any changes of an infective nature, but he states that secondary calculi, which consist for the most part of phosphate of lime, develop only in a kidney already the seat of infection.

It has been observed that as a complication of spinal-cord lesions secondary stones may occur. Injuries of the kidney and mild pyelitis

have been suspected of promoting the formation of stone by shedding products, namely, epithelial detritus, fibrinous deposits, or small blood-clots, which may serve as a focus for the deposit of lime-salts.

It is a very much over-used custom to place the blame on heredity when through lack of intelligence or diligence we are unable to find the true cause of a disease. I believe that heredity is a secondary factor—a mere tendency which may be aggravated by geographical location and mode of living. If different generations of one family remain in the same environment, eat the same foods, and drink the same water, and are exposed to identical causes, we may expect to find the same pathological condition in each generation.

One of my patients was raised in a part of Scotland where the family had resided for three generations. Kidney stones are known to have occurred in each one, paternal grandfather and two uncles died of this disease. One of his brothers has had occurrences of renal calculi. He states that this was one of the most common diseases of that territory, and he holds it due to their drinking water, which he describes as "heavily charged with lime." He left that territory early in his youth and came to western Canada. He was aware of no kidney trouble until thirteen years ago, when he became engaged in railway construction and went to a territory which had very much the same quality of water as his native home in Scotland, and within a short time he began passing white stringy material which had the appearance of fine sand. On drying this substance it looked very much like plaster of Paris. The frequent attacks of renal colic undoubtedly were due to the passage of this substance and gravel which has persisted ever since. Though he took an autogenous vaccine in 1911 for three or four weeks, the same symptoms and attacks of renal colic continued. X-rays in 1910 did not show any stones present in the kidney or ureter. Later he received A. G. No. 3 irrigations of the pelvis of both kidneys, but this also had no influence on the attacks.

In 1916 he joined the Canadian forces and went to France. While there symptoms became more severe than ever before and he was forced to leave the service in September, 1917. He then consulted Doctor Fenwick, of London. X-rays taken at that time showed a large stone in his left kidney but none in the right. He was operated by Doctor Fenwick, and one large stone was removed from the left kidney. In spite of very rigid routine of living and a meat-free, limited diet, he had in a few months a second crop of kidney stones. This time X-ray demonstrated both kidneys to be involved, showing one large recurrent stone in the left and three in the right. It almost appears that once the kidney mechanism becomes used to the act of such calcification in some cases it is difficult to prevent this process of stone formation.

In October, 1918, he consulted me. In passing ureteral catheter no obstruction was encountered. Urine examination gave specific

gravity, 1016; alkaline reaction; traces of albumin, but no sugar. Microscopic examination showed pus present in the urine of both kidneys. Radiographs verified the previous findings. Immediate operation was suggested and performed, when I removed three stones from the right kidney. As these stones were caught in the calyces, it did not seem wise to attempt their removal from the pelvis, but a small incision was made into the kidney. After the removal of the stones a small rubber tissue drain was introduced into the pelvis of the kidney for drainage. I explored the right first, as I thought that possibly it might be necessary to remove the left kidney at the second operation.

Three months later I removed from the left kidney a large stone which was embedded deeply in one of the calyces. Analysis of the stones removed at these two operations showed that they were composed of mostly calcium, magnesium, phosphate and carbonate. Therefore, as an after-treatment, I have had the patient drink very freely of water and for the past five months distilled water exclusively. In the meantime I have allowed him a rather general diet including meat. Unless I have been successful in removing the direct cause of this peculiar action of the kidney, either through the surgical interference or through the subsequent regulated diet, I am prone to believe that in course of time we will find a second and perhaps a third crop of stones. So far I am happy to state that there seem to exist no signs of kidney stones. He has no renal colic and the urine has shown considerable improvement in its chalky appearance and composition. The pus has entirely cleared up and the X-rays show no evidence of recurrence.

The surgeon cannot shake off all responsibility for a recurrence, but at the time of the operation must consider the possibilities of his work being the very cause for a future recurrence. Often in order to abstain from cutting into the kidney tissues, undue effort is made to remove a large stone through a small opening into the pelvic cavity and the stone is crushed or small fragments are scraped off and remain in the kidney. On such concrements, regardless of their size, the constituents of the urine may be deposited and a new set of stones formed.

During operation a well-lodged stone in its removal may injure the tissues, especially that of the ureter, and give rise to ureteral strictures, which will later promote the formation of ureteral stones.

Though we find many a stone in the whole of the urinary tract unassociated with any infection pre- or post-operative, yet I am inclined to believe with Hunner that the occurrence of an infection favors stone formation, especially of the recurrent type, by intensifying inflammation of a mal-functionating kidney, causing perhaps more serious and epithelial exudate and by decomposing the urine and setting free its solid constituents which may serve as substance for another set of stones. Thus I cannot help but speak emphatically of the importance of " good surgery "

in its full sense, if we are not to contribute to the recurrence of renal calculi.

In order to do our part as surgeons well we are partly dependent on the pre-operative correct localization as well as accurate diagnosis. Then our approach must be direct and the removal of stones as clean as possible. Though little has been written about the preventatives of this disease, much has been said about the technic of the operation. In the hands of a well-trained surgeon the operation entails a very small mortality risk. But when we come to consider the fact that various operators have placed the percentage of recurrent stones in the kidney at from 10 to 48 per cent., it behooves us to look about most earnestly to find out why this big divergence in statistics. I think that the investigators who reported 48 per cent. recurrence gathered cases from hospital statistics where there were a number of operators doing the surgery and perhaps, therefore, there was not a uniform surgical technic as in the institution where the small percentage of recurrence was made.

I feel that it is within my subject to speak of the importance of the different diagnostical means at hand at the present time. In no branch of medicine is the diagnostical value of X-ray more firmly established than in the examination of the urinary tract. Yet surgeons cannot afford to absolutely rely on the picture, but cystoscopic examinations must help him in the correct interpretation of the X-ray picture. There is no medical field where an absolute coöperation between the cystoscopist, röntgenologist and the surgeon is as imperative. I am putting the importance of the surgeon last, as his work depends on the painstaking and correct diagnosis of the pathological condition.

The correct interpretation of radiographs of the kidney is among the most difficult, as the kidneys themselves are only slightly more resistant to the rays than the surrounding abdominal organs lying in the path of the rays. The liver, which often shows greater resistance, is apt to obscure the upper pole of the right kidney.

Calculi, due to their chemical make-up, offer more resistance to the rays and allow a less amount of ray penetration and are therefore more easily detected; yet often they escape recognition, or when recognized they are difficult to be definitely localized. If they are composed of mostly calcium oxalate they are easily detected, but the uric acid calculus is very permeable to the röntgen rays. Fortunately, such are rare, but generally stones are made up of different ingredients and never of just one. Still, in spite of this fact, they may escape or mislead the expert röntgenologist. Calcified glands, small fecal concretions, especially when surrounded with gas, may lead us to suspect them to be renal calculi.

When stone in the right kidney is suspected, it is well to bear in mind its possibility of being a gall-stone, therefore it is wise to carefully scrutinize the location, the form and the character of the suspected shadow. Gall-stone shadows are located higher up, on or above the eleventh rib. They are generally identified by their concentric layers

and density. Still there are a great many that escape recognition. Fortunately, we have other diagnostical means at our disposal which may help to clear up all doubt in at least a large percentage of these cases. Pyelography has proven itself to be of great value, as it will demonstrate any considerable change in the outline of the renal pelvis, which is apt to be the case if obstruction of its normal outlet is present.

In short, I wish to emphasize the importance of a coöperative examination that must precede operative treatment.

The localization of kidney stone and its removal are necessarily only the first steps toward the possible cure of the disease. A great deal may depend on the after-treatment, which must be a preventive treatment. The points that I wish to make in regard to the treatment of recurrent nephrolithiasis are:

1. That we cannot hope to prevent the recurrence of this disease unless we know more of its true etiology.

2. Careful study of the history of the patient in all its different aspects and thorough examination of the urine and chemical analysis of the stone may determine the post-operative treatment.

3. Thorough flushing of the urinary channels through drinking freely of water, preferably of distilled water, may help in the dislodgment and removal of any possible nucleus of future stones. This treatment must be continued for a considerable period even after the urine has completely cleared up.

4. Faulty or incomplete surgery by leaving in the pelvis fragments of stones may contribute toward a recurrence of nephrolithiasis.

HOUR-GLASS BLADDER: REMARKS ON THE RESECTION OF THE BASE OF THE BLADDER FOR TRANSVERSE SEPTA *

By John R. Caulk, M.D.
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Abnormalities of the bladder are becoming more and more frequently observed since our diagnostic facilities have been so much improved. I wish to report two cases which seem to offer enough clinical interest to be worthy of presentation before this association. The term " hour-glass bladder " is rather confusing, since the cause of the deformity seems to assume so many pathological variations. Really, there are but few hour-glass bladders described. Fuller's cases, which were reported before this association in 1900; Pagenstecher's cases, as well as those of Pielicke, Fothergill and Passow; the anatomical reports by Orth, and the one of Squier seem to comprise about all the cases presented. The case of Squier, of course, gave an hour-glass appearance, but was due to a diverticulum; the others were hour-glass deformities due to the contraction of the bladder itself. Anatomically those bladders are definitely hour-glass. The cases which I wish to report are anatomical and physiological hour-glass bladders. By this I mean that there is a physiological contraction of the bladder over the dome in the same segment with the transverse septum of the base.

In the cases of Pagenstecher and Fuller the contraction was anterior to the ureteral orifices, and these orifices were in the upper chamber. Mine showed a partition across the base of the bladder, about one inch behind the interureteric bar, which divided the bladder base into two compartments, the ureteral orifices being in the anterior or lower chamber, similar to the cases of Fothergill and Passow, cited by Legueu. My excuse for presenting these cases is to call attention to the surgical technic which was employed for the removal of these partitions.

Various degrees of hypertrophic bands are frequently seen in the obstructed or in the neurogenous bladder, and most are coincidental rather than causal factors in the production of symptoms, and I dare say that most of them are of a congenital nature with a superimposed pathological process. One of my patients had several congenital deformities, *viz.*, hare-lip and hypospadias; the other one had not. Hypertrophies of the interureteric bar are not uncommon, and incisions by cautery or by knife either suprapubically or endovesically have been reported.

Case I.—M. B., Milwaukee, Wis., male, aged forty-two years. Complained of frequent painful urination, painful defecation, pain in the bladder and rectum.

Family History.—Negative.

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* Read before the American Association of Genito-Urinary Surgeons, June 16, 1919.

Past History.—Had scarlet fever and diphtheria as a child, with no complications. Frequent bed wetting until nine years of age. Until thirty-five years he was in fairly good health. In 1908 suffered a nervous breakdown and shortly after this had a protracted fever which was supposed to be typhoid, but which impresses one as having to do with urinary toxæmia. He gave no history of venereal diseases. In the patient's younger days he had been mentally quite active and alert, was an editor and magazine writer.

Present Illness.—Since 1908 the patient has been extremely nervous, has had a great deal of digestive disturbance, mental depression, drowsiness, and headaches. At times would fall asleep at his desk, and has even fallen asleep riding a bicycle. Two months after the beginning of this illness, he began to have trouble with his bladder, *viz.*, frequent, painful urination, at first with blood. This was treated by internal medicines and irrigations and improved. In 1912, after suffering constantly with his bladder, he had another severe nervous attack. We catheterized and a pint of residual urine was removed. Since this time he has suffered constantly with pain in the bladder and rectum, general depression, drowsiness, weakness, exhaustion, frequent chills and fever. An interesting feature of his history is that he noticed that he could urinate much more freely lying down than he could standing, and later could urinate only while flat on his back. Since 1915, that is, a year before admission, he had complete retention, and since has been on catheter life. Catheterization has always been painful and frequent, often every fifteen minutes. He has been diagnosed by several men as having a nervous lesion.

Examination.—Patient is a pale, poorly nourished individual, very drowsy. Eyes normal and general neurologic examination negative. Has a hare-lip, but not a cleft palate. Heart, lungs and abdominal examination negative. There is a balanic hypospadias, otherwise external genitalia are negative. Rectal examination shows slight relaxation of the sphincter; prostate and vesicles chronically inflamed, but small; lumbar puncture, negative; phenosulphonphthalein test less than 40 per cent. Blood examination normal, except for slight loss of the hæmoglobin. X-ray of the spine, negative; proctoscopic examination shows normal mucosa but there is a note that the bowel seems fixed anteriorly.

Cystoscopic Examination.—Complete retention of urine; bladder capacity 500 c.c. Cystoscopic shows a slight median bar, moderate relaxation of the internal sphincter; marked trabeculation of the bladder; hypertrophy of the interureteric bar; about three-fourths of an inch behind the interureteric bar is an elevated band which runs transversely across the base of the bladder, fans out on each lateral wall, and has a concavity anteriorly, giving the bladder a double pouch, the bas-fond in front and another pouch behind. Mucous membrane over the bladder bar is pale.

With negative neurologic findings, except for a suggestive internal orifice and slight relaxation of the rectal sphincter, I decided

to do a suprapubic operation, designed to remove both the median bar obstruction and the transverse band across the bladder, which seemed to project at least one-half inch. This operation was done in February of 1916. Mid-line suprapubic incision under gas and ether showed the bladder to be quite large. It was freed thoroughly. This step, the mobilization of the bladder before attempting resection, is very important in all operations for bladder resection. Upon opening the bladder it was found that there was very little obstruction at the internal orifice; this band, previously alluded to, was quite marked, being tense and firm. The interesting finding was next encountered. The bladder wall back of the band was very redundant and freely movable. By grasping it with a mouse-toothed forceps, the bladder mucous membrane, well back on the base, could be carried over the bar and pressed into the neck of the bladder, offering a satisfactory explanation for the initial attacks of retention and for the peculiarity which the patient had in not being able to urinate standing as well as lying. The surgical procedure adopted was a resection of an elliptical area across the base of the bladder four inches transversely and about three inches antero-posteriorly. This removed the bar which was in the anterior part of the resected portion and took away enough of the redundancy to allow the bladder wall to be brought together without tension. The mucous membrane seemed to be particularly freely movable over the musculature in this posterior pouch. The septum was very fibrous, hard and extended through the bladder wall with perivesical adhesions, so that there was some difficulty in removing it from the surrounding tissue. This was done without complications, and after the posterior bladder wound had been closed the bladder really had the appearance of a normal one. Ureter catheters were then passed well up in each ureter with an attempt to keep the bladder dry. I may say that I do this very frequently in bladder resections and have found it a very valuable adjunct. Catheters are brought out through suprapubic drainage tube. The median bar was then removed, the bladder closed anteriorly around a tube, two drains passed around the bladder to the base in the neighborhood of the suture line, and a small drain in the space of Retzius. The suprapubic wound closed as usual. The patient made a prompt and satisfactory recovery, having not the slightest complication. The tissue drains were removed from forty-eight hours to four days, catheters removed the fourth day, suprapubic tube on the eighth day. At the end of four weeks the wound had healed and the patient was passing his urine naturally. I have just received a letter from him stating that he is having no trouble with his bladder and is in better health than he has been for years. As he describes it, he is "full of pep."

Case II.—Mrs. W., Fort Worth, Texas, forty-two years of age, consulted me in March, 1919, complaining of painful, frequent urination without relief; pain in the right kidney and bladder.

Family History.—Negative.

Past History.—Always healthy except for attacks of appendicitis

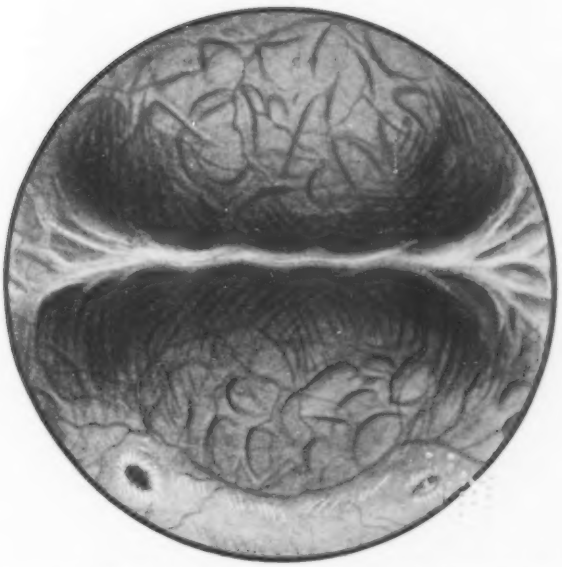

FIG. 1.—Showing congenital band of scar across base of bladder, and patency of right ureteral orifice.

FIG. 2.—Hour-glass or dumbell bladder. Regurgitation of fluid up ureter into kidney pelvis.

FIG. 3.—Bladder after operation. Liberty Bell bladder.

from sixteen to twenty-five years of age when appendix was removed with cure. Menstrual history, negative. Married in 1907, had one child fifteen months after marriage. Difficult labor, torn, repaired with excellent result. One miscarriage since.

Present Illness.—First bladder trouble started four months after marriage. Onset sudden with frequent burning urination, terminal hæmaturia. Was sick one month. Associated with this she gives a typical history of pelvic inflammatory disease for which she was treated without surgery. No further bladder trouble for four years. All during her married life she says she has used vaginal suppositories of bichloride to prevent conception and they have always burned her. In 1912 she had another sudden bladder attack which lasted for six months. At this time she had to get up five to seven times at night to urinate. Bladder was treated by local instillations, irrigations and urinary antiseptics. At this time the patient was found to have no kidney involvement and she had never suffered any kidney symptoms. Following this she was well until June of last year, when another sudden attack occurred; she was treated with $AgNO_3$ instillations by her doctor, and in a few days improved. Then following an instillation in the bladder, given by a nurse, she had a sudden acute pain in the bladder and became unconscious; later had a chill, high fever, vomiting, pain in the right kidney, which became severe. The temperature ran as high as 105 degrees. This lasted intermittently for two weeks. At this time she had an acute retention of urine and a large slough of bladder mucous membrane was removed through the meatus. Patient was sick at this time in the hospital for ten weeks. Since then has never had relief from her bladder and has had intermittent pain in the right kidney with pyuria. Urinates every fifteen minutes to one hour in the daytime and every hour at night, and suffers paroxysms of bearing down pain in the lower abdomen. Since last summer has experienced considerable pain in the rectum and straining. She feels that her bowels must move when her bladder empties, and *vice versa.* Recently has had an almost constant aching pain in the right kidney with intermittent fever. Has lost but little weight.

Examination.—Patient well nourished, good color. General examination of heart, lungs and abdomen, negative; nervous system negative; patient voids very frequently and seems to suffer pain and straining. Blood examination, normal; blood nitrogen, 56 mgm. to 100 c.c. X-ray, negative.

Cystoscopic Examination.—Bladder capacity restricted, holds only 150 c.c.; bladder very spastic; urine grossly clear but contained scattered pus cells and a few colon bacilli on centrifugation. Internal orifice somewhat irregular; general fine trabeculation of the bladder; trigone slightly elevated, right side somewhat retracted; right ureteral orifice was open and gaping, and looked almost like the orifice of a diverticulum. Left ureteral orifice normal; no ulceration of the bladder; no evidence of tuberculosis. About one inch back of the trigone is an elevated partition that completely crossed

the base of the bladder and fanned out on either side, causing a slight puckering of the bladder laterally, with a depression in front of and behind it (Fig. 1).

Ureter catheters passed easily to both kidneys. The urine from each was clear, the right containing a few pus cells. Intravenous phthalein appeared in three minutes on both sides; first fifteen minutes on the right, 11 per cent.; on the left, 12 per cent.; second fifteen minutes, on the right, 8 per cent.; on the left, 10 per cent. Pyelogram showed a hydronephrosis and hydroureter on the right.

Cystogram done later showed the interesting hour-glass bladder (Fig. 2); also showed the patent ureteral vesical valve with reflex up the right ureter and a complete filling of the right kidney pelvis, which was described by Kretchmer. It also shows the haustrations of the ureter from spastic contraction, which are frequently seen and which could be mistaken for strictures, but which can be relaxed by atropin. This patient was operated on April 3; suprapubic cystotomy with resection of the base of the bladder containing the transverse band. This partition was very hard, almost cartilaginous and extended completely through the wall of the bladder and was adherent to the rectum which explained her rectal symptoms. The same operation was done as in the previous case with the natural exception of the prostatic condition. Patient had a very satisfactory convalescence; the wound healed the twenty-third day. At the present time she is entirely relieved from all her pain in the bladder, rectum and kidney. She has frequent urination, although she has gone two hours in the daytime and three hours at night. The hour-glass contraction in this case was produced by the band on the base of the bladder with a spastic contraction of the muscle of the dome; there was no anatomical pathological change in the anterior wall of the bladder. Cystogram made six weeks after the operation shows but slight evidence of constriction and less of the hour-glass appearance (Fig. 3)—now a Liberty Bell bladder.

SUMMARY

I am convinced that incising these bands would not have effected a cure, as they implicated the whole bladder wall, similar to the Hunner ulcer, and nothing short of complete resection can hope to cure the patient. The operation is not hard, can be performed from without, but must be carefully done when approaching the external coat of the bladder. Hemorrhage can be easily controlled. The first case is of interest on account of the resection of such a large amount of redundant bladder wall, and is an illustration of a prolapsus which has been described by Villier, Streubel, Vary and others.

I wish to emphasize the importance of free mobilization of the bladder before resection; the value of ureter catheter drainage in bladder resection; the need of complete removal of such transverse partitions and not

temporizing with mere slit operations; the importance of vesical spasm in the neighborhood of inflammatory areas which in Case II served to magnify the hour-glass contraction; and finally, the protective value to a kidney of removing causes of vesical spasm in the presence of a patent ureteral vesical valve.

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ELEPHANTIASIS AND THE KONDOLEON OPERATION

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Elephantiasis and elephantoid conditions are brought about by the mechanical obstruction of the lymphatics or veins of the dependent part, added to which is associated the presence of microörganisms, whether it be a filaria nocturna or the streptococci. In certain tropical countries the hypertrophy and fibromatosis of the hypoderm is brought about no doubt most frequently by the filaria, but in the Gulf and South Atlantic States we find the streptococci the exciting cause. According to Matas,[1] the hysto-pathological elements necessary to complete the picture of elephantiasis are: (1) a mechanical obstruction or blockade of the veins and lymphatics of the region, usually an obliterative thrombo-phlebitis, lymphangitis or adenitis; (2) hyperplasia of the collagenous connective tissue of the hypoderm; (3) gradual disappearance of the elastic fibres of the skin; (4) the existence of a coagulable dropsy or hard lymph œdema; and, (5) a chronic reticular lymphangitis caused by the secondary and repeated invasion of pathological microörganisms, usually of the streptococcal type. With this viewpoint of its pathology we can lay aside all of the old ideas of tropical types and streptococcal type, etc. This better understanding of its pathology has led us more nearly than ever to the prospects of curing these unfortunates through the medium of an operation, which has been credited to Kondoleon,[2] of Athens, Greece, who first published his method in 1912. The oldest surgical treatment suggested for elephantiasis was that proposed by Carnochan in 1851, which consisted in the ligation of the main artery of the limb, the femoral or external iliac, with a view of diminishing the œdema. Next came the method of excising wedge-shaped areas by Mikulicz, Von Eiselsberg, Kaposi and others. None of which were, however, satisfactory. The idea of establishing a lymphatic communication between the disease and normal area seems not to have been original with Kondoleon, for in 1908 we find Sampson Handley [3] published his method known as "Lymphangioplasty," which consisted of passing long threads from the diseased area to healthy areas with the hope and expectation of establishing new lymphatic channels along the lines of these silk or linen threads. This has been much practiced throughout the civilized world, not only for elephantiasis, but for other conditions, such as the drainage of internal hydrocephalus suggested by Sharpe,[4] and many of the elephantoid conditions. However, Madden,[5] Ibraham and Ferguson, of the Egyptian government school of medicine at Cairo, showed very conclusively by their experiment that the force of gravity as well as the fibrous constriction forming about these newly formed lymphatic tubes, defeated their object and ultimately caused them

to become fibrous bands. Finally, Handley [6] himself concludes that his procedure was not applicable to elephantiasis in his Hunterian lecture on the surgery of the lymphatic system. Lanz [7] in 1906 attempted to establish drainage from the œdematous area to healthy tissue by a long incision through the skin and fascia lata (which acts as a shelf between the superficial and deep lymphatics) by planting pedunculated strips of this fascia lata into trephined openings in the femur. In addition many smaller openings were made in the fascia lata. Oppel [8] and Rosanow [9] also contributed to this idea of draining by planting flaps of the fascia lata into the deep muscles and extended their operation to the lower limb as well as to the thigh (Fig. 1). Evolving his ideas then evidently from those whose efforts had preceded his, but with the same fixed purpose to establish a lymphatic communication between the healthy infra-aponeurotic tissue and the diseased obstruction and hypertrophied supra-aponeurotic tissues, Kondoleon excised a large strip of the fascia lata throughout the diseased area and stitched the edges of the aponeurosis to the underlying muscle, with most gratifying results. That scar tissue will form in this gap is obvious, but the newly forming, anastomosing lymphatics and veins will establish themselves so abundantly and quickly in so large an area that they seem to resist this constricting influence. This he first reported in 1912 and later in 1915. In 1913 Matas and Gessuer report this operation, being the first to perform it in America. Later Royster,[10] Hill,[11] Barber,[12] Moschcowitz,[13] and Sistrunk reported success with it. Sistrunk [14] especially, whose large experience with it in the Mayo Clinic has added much to its refinement.

Case I.—Mrs. M. presented herself on April 18, 1919, with elephantiasis of the right limb. Was born at Swansboro, Georgia, in 1894 and lived there until eighteen years of age, when she moved with her family to Savannah. The swelling of the limb began when she was seventeen years old. She was married when she was fifteen. Had a severe childbirth with pelvic infection and milk-leg at seventeen. Since then the limb has gradually become larger. During this period of eight years she has had several attacks of elephantiasis fever at which time there was an erysipelatous eruption with sudden onset of chill, fever and aching throughout the body. When she was twenty she had a laparotomy done and both tubes removed for a pelvic inflammatory condition. At the age of twenty-one she was examined for the filaria and she said it was found by one of the internes in one of the Savannah hospitals. A careful study of the blood a few months later was negative, as was also our own investigation. In January, 1918, silk threads were passed from the skin down through the deep fascia and out, numbers of these being inserted as setons from the ankle to the hip with the hope of relieving the lymphadenoma. This was after the method described by Handley in 1908 and which he himself has since abandoned. The scars of this procedure can be seen in the photographic plate. It failed abso-

lutely to relieve her (Figs. 7 and 8). She came of normal parents. Father died of valvular heart disease at the age of fifty-six. Mother living and healthy, aged fifty-five. Three sisters and three brothers living and healthy. One sister died of childbirth. During childhood she had measles, mumps, chicken-pox and whooping-cough. Vaccinated against small-pox. No hook-worm infection. Menstruation established at thirteen. Suffered dysmenorrhœa constantly until birth of the child.

Physical Examination.—Stout blond, aged twenty-five years. Weight, 148. Height, 5 feet 4 inches. Skin, mucous membrane, nose, throat and reflexes, normal. Had Riggs's disease badly several years ago, but apparently cured. Chest and abdomen, negative. Extremities, right limb much enlarged.

Measurements.—Thigh, 26 inches; above knee, 22 inches; at the middle of the calf, 20 inches, and the ankle, 11 inches.

Blood.—Smears for filaria, negative (through several nights' study). No malarial parasites. Hæmoglobin, 85 per cent. Differential count shows: polymorphonuclears, 73 per cent., lymphocytes, 25 per cent., eosinophyocytes, 2 per cent. White blood-corpuscles, 13,000; red blood-corpuscles, 5,000,000. Stool examination, negative. Wassermann blood, negative.

Operation.—Under ether anæsthesia, 1 hour and 40 minutes. Two incisions were made from the trochanter major to the external malleolus (after Kondoleon's method with modification by Sistrunk). These incisions each began at the trochanter and diverged in the thigh until they were a distance of 10 cm. apart, approaching each other slightly again at the lateral aspect of the knee to a distance of 6 cm. apart, and then diverging again to a distance of 10 cm. apart at the centre of the foreleg; gradually converging again to meet at the external malleolus (see Figs. 3 and 4). The subcutaneous tissue at the edges of the skin incisions was undercut for a distance of 4 cm. and the skin flaps held back (Fig. 5); when the fascia lata was reached a strip of it was removed about 6 cm. wide throughout the entire length of the incision. This mass, consisting of skin, subcutaneous tissue, and fascia lata, was removed *en bloc* (Fig. 6). In Kondoleon's original operation, no skin was removed. It is of a great deal of advantage, however, as Sistrunk [15] has shown, to remove about the same amount of skin as one does of the superficial fascia in order that there will be no redundancy of the skin (Fig. 6). The skin edges were approximated and sutured after careful hæmostasis. A similar flap was removed from the inner aspect of the limb from the trochanter minor to the internal malleolus, except that it was of smaller dimensions (Fig. 4). The gross weight of the tissue removed was 6 pounds. Patient showed quite a little shock after operation, but reacted nicely. Both incisions healed by primary union. Patient, however, was very anæmic and developed a double pyelitis and a diarrhœa during her convalescence, which protracted it. The pyelitis was readily relieved by washing the renal pelvis with silver nitrate solution, 1 per cent. The diarrhœa was found to be due to anacidity and disappeared under large doses of

FIG. 1.—Rosenow's case before operation.

FIG. 2.—Rosenow's case after operation.

FIG. 3.—Showing amount of skin excised from outer aspect of limb.

FIG. 4.—Showing amount of skin excised from inner aspect of limb.

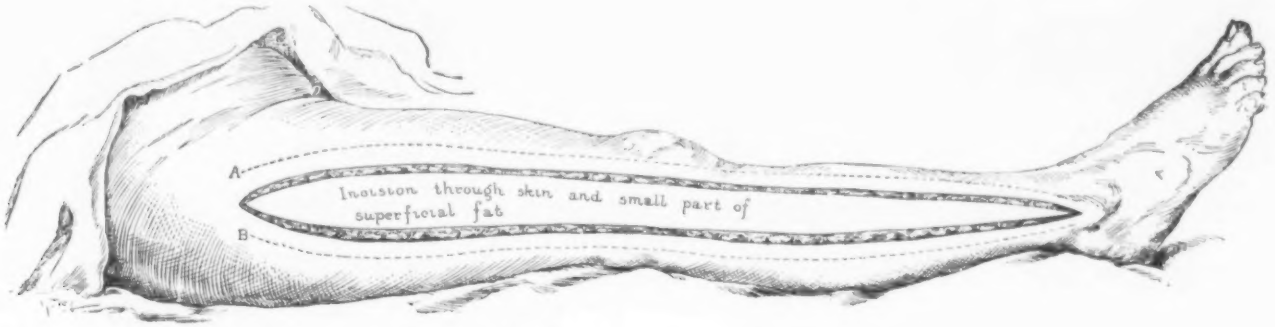

FIG. 5.—Incision used on the outer surface of the thigh and leg. Dotted lines *A* and *B* show extent to which the skin is reflected for the removal of subcutaneous fat (Sistrunk). Permission to use this illustration has been obtained from Dr. Sistrunk and J. A. M. A.

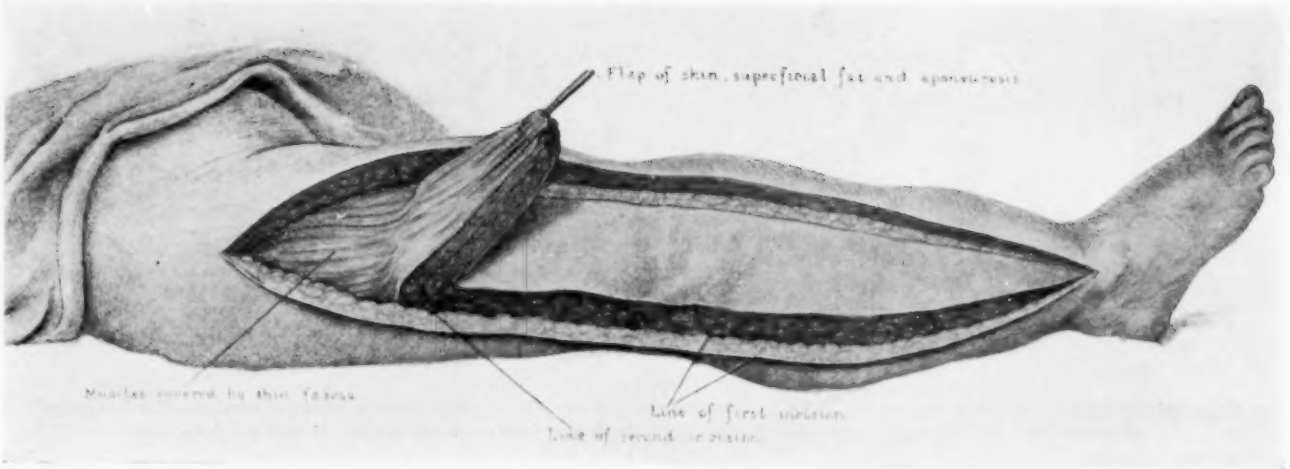

FIG. 6.—Skin, a large amount of subcutaneous fat, and aponeurosis removed in one piece (after Sistrunk). Permission to use this illustration has been obtained from Dr. Sistrunk and J. A. M. A.

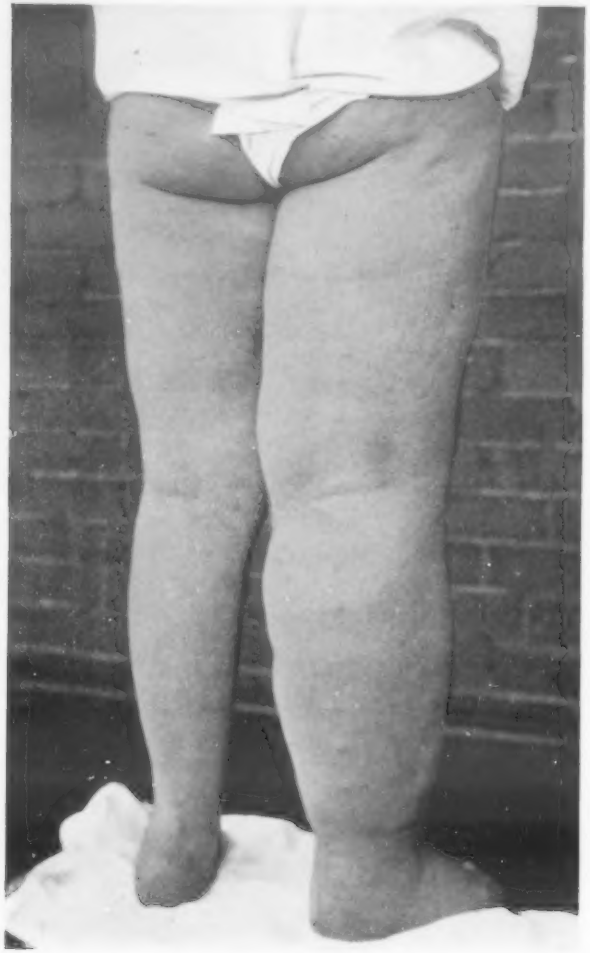

FIG. 7.—Before operation.

FIG. 8.—Before operation.

FIG. 9.—After operation.

FIG. 10.—After operation.

hydrochloric acid, diluted and taken with each meal. For the first three weeks of her convalescence, 10 c.c. doses of antistreptococci serum were administered at three-day intervals. The limb was bandaged daily before arising with an elastic bandage. She was told to continue this for three or four months after operation. She was discharged on August 5, 1919, in good condition (Figs. 9 and 10).

The change in the appearance of the limb is astonishing within a week after the operation. In that portion of the limb not reached by the incision the œdema loses its hard brawny feeling at once and resembles that of an ordinary varicose limb, subsiding very rapidly after the first week to a normal aspect, with very little pitting on pressure. There is œdema, of course, when the patient begins to walk about.

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STUDIES IN BONE GROWTH

TRIPLE CALCIUM PHOSPHATE AS A STIMULUS TO OSTEOGENESIS

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ASSISTED BY

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In presenting the experimental findings included in this paper, the author wishes to express appreciation of the resources in organization and equipment made possible through the generosity of the Surgeon General who permitted the addition of an animal research annex to the Laboratories at U. S. Army General Hospital No. 3. Such equipment and efficient technical assistance allowed the continuation of investigations in bone growth and allied subjects, from the early days of this hospital's establishment.

These animal experimentations were carried on coincidently with our clinical bone work at the hospital, with the purpose of supplementing earlier studies,[1] made about ten years ago at the Cornell Animal Hospital, relative to various phases of bone growth. Those earlier experiments included the fusing of the vertebræ of a dog by means of the inlay graft, as well as investigation of the relative osteogenesis of bone secured from different portions of the anatomy of dogs and rabbits. Other experimental findings emphasized the high osteogenetic potency of the periosteum when removed *completely*, which was quite possible if secured by *scraping* with force the outer surface of the bone with a sharp instrument. Studies were also made which bore out the inadvisability of attempting transplantation of bone from one species into another, such as dog's tissue into a sheep, or sheep's bone into a rabbit.

Among our early animal researches at U. S. Army General Hospital No. 3 have been studies in the etiology of pseudarthrosis,[2] in which attempts were made to produce this condition by use of massive and repeated exposures to the X-ray, by the removal of portions of the shafts of long bones and by various types of splinting. In all of our efforts, however, we were unable to produce a single case of pseudarthrosis, owing to the early and rapid union of the shafts of the long bones. We were able to report, however, that in our experience, no appreciable influence was exerted by the X-ray upon callus formation, there being no difference in

[1] Albee, F. H.: "An Experimental Study of Bone Growth and the Spinal Transplant," J. A. M. A., 60, 1044–49, April 5, 1913.

[2] Albee, F. H., and Morrison, H. F.: "Studies in Bone Growth: an Experimental Attempt to Produce Pseudarthrosis," Am. J. Med. Sc., January, 1920.

length of time required for union in those cases given repeated massive X-ray treatment and in their controls.

A second purpose of our research work at U. S. Army General Hospital No. 3 was to discover, if possible, a reliable artificial stimulus to bone growth. In the aim of increasing the osteogenetic activity of bone in delayed union or in pseudarthrosis, a great variety of substances have been injected into the site of the lesions, or otherwise introduced into the system. An abstract of recent literature shows that the following materials have been used for this purpose: Osmic acid, fibrin, blood, gelatine and lime salts (calcium chloride), zinc chloride, thyroidin, glacial acetic acid, iodine tincture, adrenalin, hypophysis extract, bone marrow, copper sulphate, oil of turpentine, ammonia, lactic acid (50 per cent.), silver nitrate solution, alcohol, carbolic acid (5 per cent. solution), oak bark extract (tannic), vaccines, and sera.

The very number and variety of these methods would indicate that none has proved successful in promoting osteogenesis. The great advantage, however, of such an agent has led one to the search with ever renewed enthusiasm. Early in the history of this hospital, investigations were begun on the value of triple calcium phosphate as a stimulus to bone growth. These studies have been extended over a long period of time, and the authors take pleasure in stating that they believe that an efficient and trustworthy stimulus to osteogenesis has been found in this chemical agent. Due credit should be given to Capt. Richard J. Behan, M. C., U. S. A., for the verbal suggestion of the agent.

Technic.—In all of our research work in bone growth, rabbits were used as experimental subjects, young to middle-aged adults being always chosen. Careful asepsis was invariably observed, the field of operation being treated with a 3½ per cent. tincture of iodine preparation. In our earlier studies in pseudarthrosis,[2] it was usually our method, after fracturing both bones of the foreleg, to apply an external splint for fixation and support. It was later found possible to avoid the necessity of external splinting by fracturing only one of the two bones of the foreleg, relying upon the other bone for fixation and support. We found that the wounds healed successfully when the skin edges were carefully approximated by suture and the line of suture was painted with 3½ per cent. tincture of iodine. This method was accordingly followed in all of our experiments with triple calcium phosphate, and it is of interest to report that in this whole series, numbering over 60, together with their controls, there occurred not one instance of infection.

In our investigation of triple calcium phosphate as a stimulus to bone growth, a classification of cases has been made, according to type of operative treatment. In cases of the first type, fragments of bone were first removed completely from the radius, leaving a gap in the shaft. Into this hiatus between the bone ends was then injected 1 c.c. of 5 per cent. solution of triple calcium phosphate. This was prepared by suspension of 5

per cent. of triple calcium phosphate in distilled water which was then sterilized for three successive days in the Arnold sterilizer, at 60° C. In the second type of experiment, no bone was removed nor was the radius fractured, but an attempt was made, after exposing the radius, to introduce ½ c.c. of 5 per cent. solution of triple calcium phosphate under the periosteum. The animals in all cases were radiographed frequently, and the clinical progress noted. The procedure in each type of operation is given in detail, as follows:

First Type.—After the usual preparation by shaving and iodine technic, an incision was made in the foreleg (usually the right), exposing the radius. A portion of the shaft, about one-quarter inch in length, was then removed with its periosteum intact. The wound was closed with plain catgut No. 1, and after painting the limb with iodine, the animal was returned to its cage without dressing or splint, the other bone serving in the capacity of the latter. Usually on the third day following operation, 1 c.c. of 5 per cent. solution of triple calcium phosphate was injected into the gap between the ends of the bone fragments (see Fig. 1). In a few instances the solution was injected at time of operation, before closing the skin, while in some of our later experiments the injection was made five days after fracture. These various cases will be noted in the report of the detailed experimental findings. In this type of experiment, in order that the controls might be absolutely trustworthy, the radius of the other leg of the same animal was always used, when possible.

Second Type.—In the second class of cases, the foreleg was given the same preliminary preparation as in the preceding group and the radius was exposed. The bone was not broken in these cases, but after injuring it to a slight extent by scratching with the point of the needle, an attempt was made to inject ½ c.c. of 5 per cent. solution of triple calcium phosphate beneath the periosteum of the radius with the hypodermic syringe (see Fig. 19). No controls were considered necessary in this type of experiment, as in no instance was there appreciable stimulation of osteogenesis. It is quite probable that in these cases the solution infiltrated the soft parts, and that very little, if any, actually came in contact with the bone tissues.

A detailed report of the following experiments is given:

EXPERIMENT 10.—Subject: Common hare.

March 11, 1919: Operation (first type) on right radius.

March 12: 1 c.c. of 5 per cent. solution triple calcium phosphate injected into hiatus between ends of bone.

Radiographic Findings.—March 11: X-ray shows gap of ¼ inch, with no free fragments of bone (see Fig. 1).

March 18: The ends of the shaft fragments are already beginning to close in, with some callus formation in the soft parts about the lesion (see Fig. 2).

March 25: Fourteen days after operation. Already there is evidence of union of the fragments, with a large amount of callus formation (see Fig. 3).

April 1: The gap is entirely filled. There is an increased density of callus about the site of the lesion, with more perfect solidification (see Fig. 4).

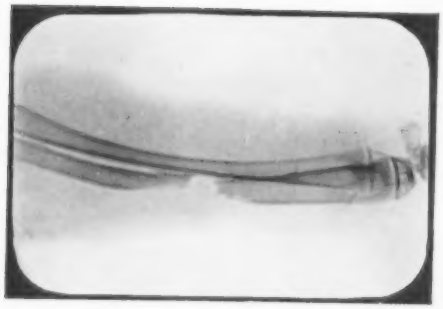

FIG. 1.—Experiment 10. Day of operation, showing gap in shaft of right radius, due to removal of about one-quarter inch of bone.

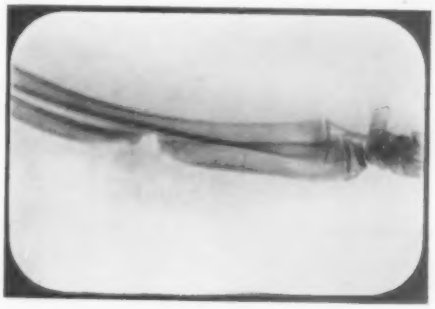

FIG. 2.—Experiment 10. Seven days after operation. Into the hiatus in the shaft was injected one cubic centimetre of five per cent. solution triple calcium phosphate, six days before this radiograph was taken. Note that the ends of the shaft fragments are already beginning to close in. There is some callus formation in the soft parts about the lesion.

FIG. 3.—Experiment 10. Fourteen days after operation. Union of the radial fragments is evident with a large amount of callus formation.

FIG. 4.—Experiment 10. Twenty-one days after operation. Note the increased density of callus formation and the more perfect solidification.

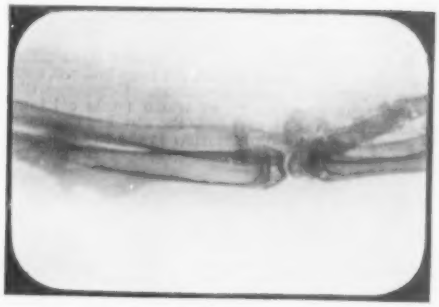

FIG. 5.—Experiment 10. Thirty-one days after operation. The exuberant callus is now beginning to flatten and to disappear in the periphery.

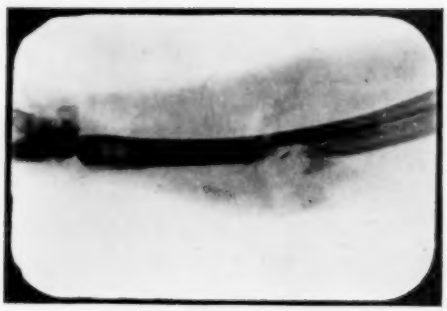

FIG. 6.—Experiment 10*a*. Control of Experiment 10. Day of operation, showing removal of about one-quarter-inch of bone from shaft of left radius. This case was not treated with triple calcium phosphate.

FIG. 7.—Experiment 10*a*. Thirteen days after operation, showing no appreciable change. Compare with Experiment 10 (Fig. 3).

FIG. 8.—Experiment 10*a*. Thirty-one days after operation. The space has not yet been bridged, and there is very little callus formation. Compare with Experiment 10 (Fig. 5), in which triple calcium phosphate was used, and note the striking contrast in amount of bone proliferation in the two cases at the same length of time after operation.

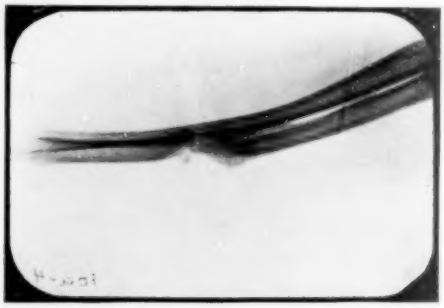

FIG. 9.—Experiment 10*a*. Forty-four days after operation. The bone is now united along one side, leaving a V-shaped defect. There is a small amount of callus.

FIG. 10.—Experiment 11. Day of operation, showing gap in shaft of right radius. On the day following operation, one cubic centimetre of five per cent. solution triple calcium phosphate was injected into this hiatus.

FIG. 11.—Experiment 11. Seven days after operation. There is evidence of some callus formation, and the distance between the ends of the fragments seems slightly decreased.

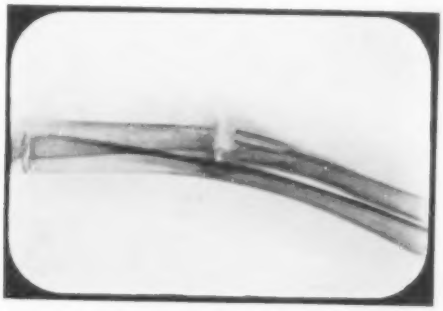

FIG. 12.—Experiment 11. Fourteen days after operation. Already union of the shaft fragments is evident, with marked formation of callus producing a plumber's "wiped joint."

FIG. 13.—Experiment 11. Twenty-one days after operation, showing the hiatus completely filled. There is solid union of the fragments, with a large amount of well-formed callus.

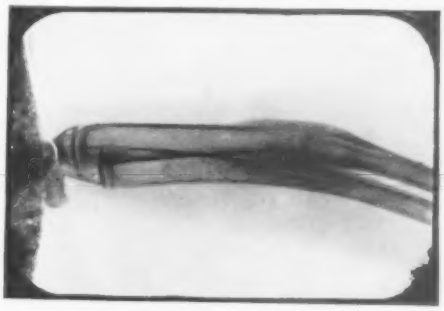

FIG. 14.—Experiment 11. Thirty-one days after operation. Much of the excess callus has now disappeared; the bone is beginning to shape itself.

FIG. 15.—Experiment 11*a*. Control of Experiment 11. Day after operation, showing hiatus in shaft of left radius. This case was not treated with triple calcium phosphate.

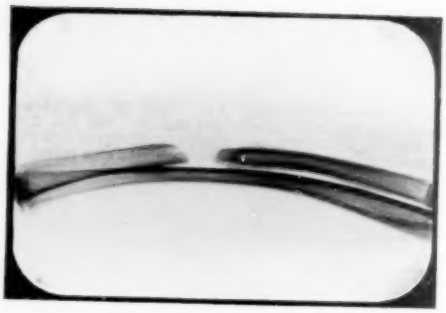

FIG. 16.—Experiment 11*a*. Twenty-nine days after operation. The gap is now about one-third closed with no excess callus formed

FIG. 17.—Experiment 11*a*. Thirty-seven days after operation. The hiatus is nearly closed. Callus formation is meagre.

FIG. 18.—Experiment 11*a*. Forty-nine days after operation. Union of the fragments is now complete.

April 11: Thirty-one days after operation. The exuberant callus is beginning to flatten and to disappear in the periphery (see Fig. 5

EXPERIMENT 10a.—Control of Experiment 10.

March 17, 1919: Operation on left radius—fragment of bone removed as in No. 10. This case was not treated with triple calcium phosphate.

Radiographic Findings.—March 17: Day of operation, showing gap in shaft (see Fig. 6).

March 30: Thirteen days after operation. There is no appreciable change, as shown in Fig 7. Compare with Experiment 10 (Fig. 3).

April 17: Thirty-one days after operation (see Fig. 8). The X-ray shows that the space has not been bridged; there is very little callus formation. Compare with Experiment 10 at the same length of time after operation (see Fig. 5).

April 29: Forty-four days after operation. The bone is now united along one side, leaving a V-shaped defect. There is a small amount of callus (see Fig. 9). Note the striking contrast between this case and Experiment 10 (in which triple calcium phosphate was used) in the amount and rapidity of bone proliferation.

EXPERIMENT 11.—Subject: Common hare.

March 11, 1919: Operation (first type) on right radius.

March 12: 1 c.c. of 5 per cent. solution triple calcium phosphate injected into gap between ends of bone.

Radiographic Findings.—March 11: The X-ray shows gap of ¼ inch in right radius, with no free fragments present (see Fig. 10).

March 18: A small amount of callus formation is noted. The distance between ends of bone seems slightly decreased (see Fig. 11).

March 25: Fourteen days after operation. Marked formation of callus is noted, producing a plumber's "wiped joint," extending from both distal and proximal fragments, with evidence of union of the fragments (see Fig. 12).

April 1: Twenty-one days after operation. The gap is now completely filled and there is solid union of the fragments, with a large amount of well-formed callus (see Fig. 13).

April 11: Thirty-one days after operation. Much of the excess callus has disappeared; the bone is beginning to shape itself (see Fig. 14).

EXPERIMENT 11a.—Control of Experiment 11.

March 17, 1919: Operation on left radius—fragment of bone removed, as in No. 11.

Radiographic Findings.—March 18: Day after operation, showing gap in shaft (see Fig. 15).

April 15: The space is about one-third closed, with no excess callus formed (see Fig. 16).

April 23: The hiatus is almost closed, with very little callus formed (see Fig. 17).

May 5: Forty-nine days after operation. Union is complete (see Fig. 18).

EXPERIMENT 12.—Subject: Belgian hare.

March 20, 1919: Operation (first type) on right radius.

March 23: One c.c. of 5 per cent. solution triple calcium phosphate injected into the defect in shaft.

Radiographic Findings.—March 21: X-ray shows gap of ⅛ to ¼ inch. There are no free fragments between ends of the bone.

March 28: There is no change in appearance.

April 4: There is very little change noted.

April 14: Union is almost complete.

April 23: There is solid union.

EXPERIMENT 12a.—Control of Experiment 12.

April 23, 1919: Operation on left radius. Fragment of bone removed as in No. 12.

Radiographic Findings.—April 24: X-ray shows gap of ¼ inch in left radius, with no free fragments.

April 30: No changes are noted.

May 8: There is very little change in appearance of radiogram.

May 16: A small amount of callus formation is noted.

May 21: There is partial union.

May 27: There is solid union.

EXPERIMENT 13.—Subject: White buck.

March 20, 1919: Operation (first type) on right radius.

March 23: One c.c. of 5 per cent. solution triple calcium phosphate injected into gap in shaft of radius.

Radiographic Findings.—March 21: X-ray shows gap of ¼ inch in right radius.

April 4: Partial closure of space is noted, with but meagre callus formation.

April 21: There is solid union, and good alignment, with no excessive formation of callus.

EXPERIMENT 13a.—Control of Experiment 13.

April 23, 1919: Operation on left radius. Fragment of bone removed as in No. 13.

Radiographic Findings.—April 24: X-ray shows a gap of ¼ inch, with no free fragments.

May 10: No changes are noted until May 10th, when the X-ray shows formation of callus, but not in excessive amounts.

May 20: There is solid union, but with no excess of callus.

EXPERIMENT 14.—Subject: Common hare.

April 3, 1919: Operation (first type) on left radius. At time of operation, 1 c.c. of 5 per cent. solution triple calcium phosphate was introduced into the bony defect, and wound was then closed.

Radiographic Findings.—April 4: X-ray shows a bony defect of ⅛ inch in the left radius. A few free fragments of bone are present.

April 12: Very little change is noted.

April 18: Fifteen days after operation, showing evidence of union of the ends of the bone along one border. Compare with Cases 10 and 11, in which union was evident fourteen days after operation (see Figs. 3 and 12). The presence of a few free fragments of bone, as noted above, should also be borne in mind.

April 30: The gap is completely filled, except for a V-shaped space on one border. Very little callus is noted.

EXPERIMENT 14a.—Control of Experiment 14.

February 13, 1919: Operation on right radius. Fragment of bone removed, as in Experiment 14.

Radiographic Findings.—February 13: X-ray shows defect of ¼ inch in right radius.

February 23: No change is noted.

March 8: The gap is about two-thirds closed, with very little proliferation of bone.

March 25: There is solid union. The outlines of the bone are very nearly normal.

EXPERIMENT 15.—Subject: Common hare.

April 3, 1919: Operation (first type) on right radius. At time of operation 1 c.c. of 5 per cent. solution triple calcium phosphate was introduced into gap between the ends of the bone fragments; the wound was then closed.

Radiographic Findings.—April 4: X-ray shows a V-shaped defect of right radius, ¼ inch across, at the open side. A few free fragments are present.

April 12: No change is noted.

April 18: The defect has closed in from each end to about one-fourth of its original extent.

April 30: Twenty-seven days after operation the defect is entirely filled, save for a slight depression on the surface of the bone. Callus formation is very meagre.

May 6: The defect is completely closed.

EXPERIMENT 15a.—Control of Experiment 15.

February 17, 1919: Operation on left radius. Fragment of bone removed as in Experiment 15.

Radiographic Findings.—February 17: X-ray shows a defect of ¼ inch in the left radius, with two small free fragments present.

February 28: Slight proliferation of bone from proximal and distal fragments is noted.

March 7: Eighteen days after operation. New bone bridges the gap, leaving a defect on the outer surface of the radius. The presence of free fragments of bone, originally left in the hiatus, may have a significant bearing on the rapid union in this case.

March 17: Union is complete, with no excess callus.

EXPERIMENTS 16 to 25, inc., which were of the second type, follow Experiment 30 given below.

EXPERIMENT 26[8].—Subject: Common hare.

June 16, 1919: Operation (first type) on right radius.

June 21: Injection of 1 c.c. of 5 per cent. solution triple calcium phosphate between the gap in the shaft fragments.

Radiographic Findings.—June 21; The X-ray shows a bony defect of ¼ inch in the right radius, with no free fragments.

July 5: Fourteen days after injection of triple calcium phosphate, good union is noted, with strong callus formation about the ends of the bone. (Compare with Cases 10 and 11.)

EXPERIMENT 27.—Subject: Common hare.

June 16, 1919: Operation (first type) on right radius.

June 21: One c.c. of 5 per cent. solution triple calcium phosphate injected into gap between the ends of the shaft fragments.

Radiographic Findings.— June 21: X-ray shows a bony defect of ¼ inch in right radius, with one small free fragment.

July 5: The defect is almost closed, with meagre callus formation.

July 10: Nineteen days after injection of triple calcium phosphate there is complete union, with little or no excess callus formed.

EXPERIMENT 28.—Subject: Common hare.

June 16, 1919: Operation (first type) on right radius.

June 21: Injection of 1 c.c. of 5 per cent. solution triple calcium phosphate in hiatus between shaft fragments.

Radiographic Findings.—June 21: X-ray shows absence of ¼ inch of bone from right radius, with no free fragments present.

July 5: Fourteen days after injection of triple calcium phosphate, the defect has been bridged by new bone. About the end of the proximal fragment callus has formed; there is no evidence of callus about the distal portion.

EXPERIMENT 29.—Subject: Common hare.

June 16, 1919: Operation (first type) on right radius.

June 21: One c.c. of 5 per cent. solution triple calcium phosphate injected into gap between ends of bone.

Radiographic Findings.—June 21; The X-ray shows a loss of ¼ inch of substance from right radius. A few free fragments are noted.

July 5: Fourteen days after injection of triple calcium phosphate, the defect is bridged by new bone, but the hiatus is not completely filled. There is no excess of callus formation.

July 12: The gap is completely filled and there is solid union. Note, also, in this case that a few free fragments of bone were originally left in the hiatus between the ends of the shaft fragments.

EXPERIMENT 30.—Subject: Common hare.

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[8] Experiments 26 to 30, inclusive, have no controls.

June 16, 1919: Operation (first type) on right radius.

June 21: Injection of 1 c.c. of 5 per cent. solution triple calcium phosphate into gap beween ends of bone.

Radiographic Findings.—June 21: The X-ray shows a loss of ¼ inch of substance from right radius, with no free fragments present.

July 5: The defect is almost closed, with a large amount of callus formed on the adjacent surface of the ulna.

July 14: Twenty-three days after injection of triple calcium phosphate, there is solid union, with a moderate amount of callus.

EXPERIMENTS 16 to 25, inclusive (Second Type).—These experiments were all of the second type, the first five being done on one litter of rabbits of adult age, using the right radius; the last five being performed likewise on animals of one litter, the left radius being used in these latter instances.

Cases 16 to 20, inclusive, were injected with ½ c.c. of 5 per cent. solution triple calcium phosphate on May 6, 1919. Radiographs taken as late as June 12th (thirty-seven days after operation), failed to show the slightest formation of callus, or of new bone. Illustrative of experiments of this group is Case 17. It was possible to observe this case forty-four days after operation, at which time radiographic findings were negative (see Figs. 19 to 22).

Cases 21 to 25, inclusive, were injected on May 12, 1919. Radiographs taken thirty-one days after operation, on June 12th, were negative.

CONCLUSIONS

1. Cases of fracture, with loss of substance, showed a much more rapid bone growth and union when triple calcium phosphate was injected into the gap between the bone ends than did the controls without its use.

Of the cases treated with this agent, especially remarkable bone formation is shown in Experiments 10 and 11 (see Figs. 1 to 5 and 10 to 14).

2. Callus formation in the cases of fracture treated with triple calcium phosphate extended far into the soft parts, apparently following the penetration of the solution (see Figs. 3, 4, 5, 12 and 13). In some cases, the callus even extended out beneath the skin.

3. For our entire series of experiments, the average length of time for union in cases of fracture treated with triple calcium phosphate was thirty-one days.

The average length of time for union in the controls was forty-two days.

In our total series, therefore, cases of fracture treated with triple calcium phosphate showed union at least eleven days earlier than did the controls; in other words, union in cases stimulated by this agent occurred in 73.81 per cent. of the time which seemed to be required in the controls. For the smaller number of experiments, herewith reported in detail, even more striking relationships may be observed. The average number of days elapsing between date of injection of triple calcium phosphate and the first radiographic evidence of union in these experiments[4] was 19.

[4] In rare instances, it was found by early radiographic examination that one or more free fragments of bone were present in the hiatus between the ends of the shaft. In such cases, already noted in the foregoing detailed reports, an added influence on rapidity of bone growth may have been exerted by these loose fragments.

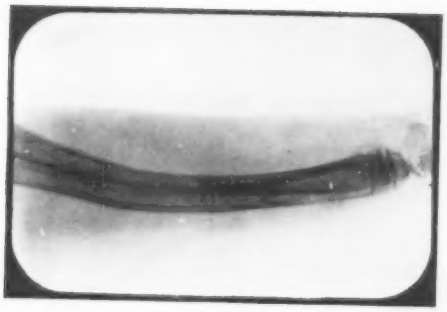

FIG. 19.—Experiment 17. Ten days after operation of the second type. In this case no bone was fractured, but an attempt was made to inject one-half cubic centimetre of five per cent. solution triple calcium phosphate subcutaneously beneath the periosteum of the right radius. Note that no shadow is cast by the solution.

FIG. 20.—Experiment 17. Showing case twenty-four days after injection of triple calcium phosphate. There is no change apparent.

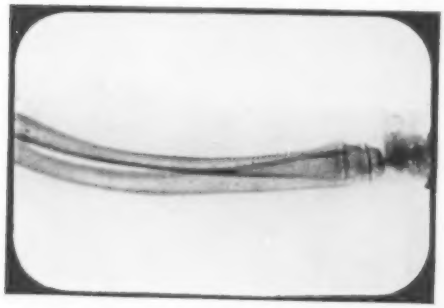

FIG. 21.—Experiment 17. Thirty-seven days after injection of the solution. The radius remains unchanged.

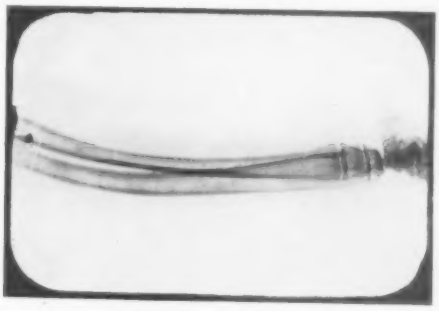

FIG. 22.—Experiment 17. Forty-four days after injection of triple calcium phosphate. Note that in this case there has been no apparent stimulation of bone growth, even to the slightest degree.

Furthermore, of these cases, over 50 per cent. showed union by the fifteenth day after injection of the agent.

In computing the length of time required for union to take place, some error may arise owing to the impossibility of determining the precise time at which union of the fragments occurred. With due allowance for error, however, the decided advantage in favor of the cases treated with triple calcium phosphate is evident.

4. No appreciable bone growth was stimulated by an attempt to inject triple calcium phosphate beneath the periosteum of the radius in cases of the second type, in which the bone was not fractured. Undoubtedly the solution in such cases infiltrated the soft parts overlying the periosteum and did not actually come into contact with the bone-growing tissues.

It is evident that osteogenesis was stimulated by triple calcium phosphate in conjunction with fracture, or, in other words, with trauma of sufficiently great severity to open up those bone surfaces containing active bone-growing cells, namely, the periosteum, compact bone, endosteum and marrow, thereby allowing the intimate contact of the solution with these tissue layers.

5. It was demonstrated in the early portion of those experiments in which an attempt was made to inject triple calcium phosphate subcutaneously beneath the periosteum, that the solution itself did not produce an X-ray shadow, since all the radiographs were entirely negative, thus ruling out any possible error in this respect (see Fig. 19).

Moreover, callus formation in all our series of cases treated with triple calcium phosphate seemed in no degree inhibited by frequent exposures to the X-ray. This had already been clearly demonstrated in our earlier studies in pseudarthrosis.[2]

6. No toxic symptoms were noted in any of the cases treated with triple calcium phosphate. At no time did this agent act as an irritant locally.

7. In our animal experimentations, only one injection of triple calcium phosphate was administered in each case treated. We would offer the suggestion that the stimulating action of this agent might be increased by *repeated* injections at frequent intervals in unfavorable clinical cases of pseudarthrosis, whether or not preceded by a bone graft operation.

8. It is believed that these findings with triple calcium phosphate are of sufficient value to warrant their clinical application. We wish to state that this agent is now being tried upon human subjects, and a report of these results will be subsequently presented.

A STUDY OF THE CAUSES OF DELAYED UNION AND NON-UNION IN FRACTURES OF THE LONG BONES*

By William Laurence Estes, Jr., M.D.
of Bethlehem, Pa.

Stimulated by the observation of Dr. Joseph A. Blake[1]—that the suspension-traction treatment as used by him in gunshot fractures leads to more rapid union, especially in uninfected comminuted fractures—a review of fractures of the long bones treated in our clinic at St. Luke's Hospital, Bethlehem, Pa., from September 1, 1915, to January 1, 1919, has been undertaken, primarily to ascertain any clinical factors that may bear upon the question of union, and incidentally to investigate the effect of former methods of treatment upon comminuted fractures.

General Considerations.—A fractured bone may unite in what may be considered normal time; the time for union may be greatly increased; or complete bony union may never occur. We have, therefore, from the point of time: 1. Normal union. 2. Delayed union. 3. Non-union.

Delayed union and non-union may be due to:

I. *General Causes.*—1. Nervous diseases, such as tabes dorsalis, and general paresis. 2. Constitutional disorders, such as gout, diabetes, osteomalacia, chronic nephritis. 3. General infections. (*a*) Erysipelas and acute exanthemata, measles, scarlet fever, typhoid fever, etc. (*b*) Syphilis. 4. Old age. 5. Starvation, insufficient nutrition, scurvy. 6. Anæmia: (*a*) Severe hemorrhage. (*b*) Pernicious anæmia. (*c*) Grave secondary anæmia.

II. *Local Causes.*—1. Mechanical interference with fracture union: (*a*) Separation and displacement of the fragments. (*b*) Interposition of soft tissues between the fragments. (*c*) Incomplete immobilization after reduction of fracture.

2. Deficient blood supply: (*a*) Injuries to the nutrient artery of the affected bone. (*b*) Severe trauma to soft tissue adjacent to fracture. (*c*) Severe trauma to bone and periosteum, causing a partial or complete loss of continuity.

3. Bone lesions: (*a*) Osteomyelitis-necrosis. (*b*) Tumors—primary or secondary—in which pathological fractures have occurred.

4. Infection of the soft tissues.

5. Nerve injury.

III. *Treatment of the Fracture Itself.*

The following observations are based upon records of 374 fractures of the humerus, radius and ulna, femur, tibia and fibula. It is the purpose of this study to peruse the records submitted—to ascertain

* Read before the Association of Resident and Ex-Resident Physicians of the Mayo Clinic, October 8, 1919.

the relative frequency with which delayed union and non-union have been found; and to analyze these findings, to determine what especial factors play a part in the prevention of proper recovery in fractures. It is obvious, however, that, in many instances, the decision will be complicated by evidence indicating that, in a given case, there is far more than a single criminal at whom an accusing finger may be pointed.

To determine whether delayed union had occurred or not, a tabulation of the time of union of the uncomplicated fractures for each location was made. The majority were found to fall between certain limits. All fractures found to require approximately eight days more for union than the upper normal limit were regarded as showing delayed union. For instance, in fractures of the lower third of the tibia, union was estimated as occurring normally in from thirty to forty-two days; all fractures requiring fifty days or more were considered to exhibit delayed union. Union must not be confused with consolidation. Union was considered in this paper to occur when no vestige of abnormal mobility could be detected at the seat of fracture, and had no relation to the strength of the repair. If, after six or more months, the repair of the bone had reached a standstill, and abnormal mobility still persisted, non-union was believed to have occurred.

Location			Delayed union	Non-union
Humerus, 50	Upper end	15		
	Shaft	27		
	Upper 3d	10		
	Middle 3d	12	2 (16⅔%)	1 (8⅓%)
	Lower 3d	5		
	Lower end	8		
	Delayed union	4%		
	Non-union	2%		
Radius and ulna, 67	Upper end	6		
	Head of radius	1		
	Olecranon	5	1	
	Shaft	45		
	Upper 3d	8	1 (12½%)	1 (12½%)
	Middle 3d	9	3 (33%)	
	Lower 3d	28	7 (25%)	
	Lower end	16		
	Delayed union	18%		
	Non-union	1.4%		
Femur, 81	Upper end	23		
	Neck	15	1 (6⅔%)	4 (26%)
	Trochanteric	8		
	Shaft	55		
	Upper 3d	13	2 (15%)	

Furthermore, of these cases, over 50 per cent. showed union by the fifteenth day after injection of the agent.

In computing the length of time required for union to take place, some error may arise owing to the impossibility of determining the precise time at which union of the fragments occurred. With due allowance for error, however, the decided advantage in favor of the cases treated with triple calcium phosphate is evident.

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	Neck	15	1 (6⅔%)	4 (26%)
	Trochanteric	8		
	Shaft	55		
	Upper 3d	13	2 (15%)	

			Delayed union	Non-union
Femur	Shaft, Middle 3d	30	7 (23%)	.....
	Lower 3d	12	5 (41⅔%)	.....
	Lower end (condylar)	3	.....	.....
	Delayed union	18.5%		
	Non-union	5%		
Tibia, 140	Upper end (condylar)	1	.....	.....
	Shaft	119		
	Upper 3d	24	13 (54%)	1 (4%)
	Middle 3d	43	12 (30%)	1 (2%)
	Lower 3d	52	10 (20%)	2 (4%)
	Lower end	20	.....	.....
	Delayed union	25%		
	Non-union	2.85%		

Fibula, alone, 38. No cases of delayed union, and no cases of non-union.

Summary

Humerus: Delayed union and non-union seem fairly confined to the middle third.

Radius and ulna: Delayed union is more prone to occur in the distal half.

Ulna: Non-union occurs more frequently in the upper third.

Femur: Non-union is more likely to occur in the neck. In the shaft, the distal third seems more liable to suffer delay in union.

Tibia: Delayed union and non-union seem fairly equally distributed over the entire shaft, with a greater tendency to delayed union in the upper third, and to non-union in both upper and lower thirds.

Discussion

The middle third of the humerus and the neck of the femur are quite generally recognized as localities where delayed and non-union are likely. Stimson [2] believed "delayed union occurred more frequently in the upper limbs." Jones,[3] in referring to shaft fractures, mentions the juncture of the middle and upper thirds of the humerus, the middle of the femur, and the lower third of the tibia and fibula as the most common sites of delayed union. Our statistics seem to approximate fairly closely Jones' findings, and show a greater percentage in the lower extremities, especially in the tibia. Blake [4] has observed in war fractures that repair in the tibia is more indolent than elsewhere in the body, and ascribes it to the lack of soft parts over the bone.

The fractures of the neck of the femur deserve a somewhat detailed consideration. The cases have been difficult to trace; 4 resulted in non-union; 1 in delayed union; 2 died. In 3 others, the result cannot be definitely stated. Of the 4 cases of non-union, all were intra-capsular, 3 were over seventy-five years of age, and 1 between fifty and sixty. The treatment consisted in the application of a plaster cast in extreme abduction as advocated by Whitman, with preliminary manipulation for reduction in unimpacted cases, or simple suspension in abduction by a Hodgen splint. Cotton's method of impaction was not used. Deficient blood supply of the proximal fragment, and the cancellous character of the part of the bone in-

volved, have been assigned as reasons for non- and delayed union. Doctor Henderson,[5, 6] of the Mayo Clinic, in the last year or two has done much to improve operative technic for the cure of non-union in this group of cases, and has suggested that their great incidence may be due to the lack of proper primary treatment of the fresh fracture.

ANALYSIS OF THE CAUSES OF DELAYED UNION

In the 64 cases of delayed union, the cause of delay has been ascribed to:

1. Comminution		6
2. Compound fracture		34
a. Simple	4	
b. Compound fracture and comminution	15	
c. Compound fracture with comminution and infection of the soft tissues	3	
d. Compound fracture, with comminution and osteomyelitis	12	
3. Plating alone		6
4. Late open reduction		3
5. Mal-union from incomplete reduction		4
6. Undetermined		9
7. Plating for comminuted fracture—infection		1
8. Multiple fractures		1

NOTE.—Syphilis existed in 3 cases.

It will be noted that local causes which have to do with deficient blood supply, bone lesions or infection, account for the majority of these delayed union cases. A certain number show delay as the result of the treatment of the fracture itself, and, in addition, it will be observed that none of the ascribed "General Causes" figure in this analysis, except syphilis. In 15 cases, during treatment, acute exanthemata occurred (which included typhoid fever, measles, pneumonia, and diphtheria), as well as erysipelas, acute follicular tonsillitis and two cases of delirium tremens. In none of these was there any delay in union. (There were besides two cases that died of uræmia, one of diabetes, and one of septicæmia.)

Three cases of compound, comminuted fracture of the tibia were found to be syphilitic. No manifestations of the disease were apparent, and infection was not definitely admitted, but the Wassermann taken on suspicion, was 4——. Specific treatment seemed, in two cases, to hasten definitely the bony union. The third case developed a severe staphylococcus aureus infection of the leg, after five months of persistent non-union. He finally required amputation. There was no gummatous formation nor did the wound present the appearance of syphilitic ulceration in any of these three cases. But no examination for spirochætes was made directly from the wound. It would therefore seem advisable in all cases of delayed union—even in the absence of history or definite indications of syphilis—to have a routine Wassermann done.

Though it is well known that in the later years of life the time of union is likely to be increased over normal, in our series age seems to have had very little influence, as the following tabulation demonstrates:

Delayed union under ten years, 1; ten to twenty years, 10; twenty to thirty years, 14; thirty to forty years, 17; forty to fifty years, 13; fifty to sixty years, 5; sixty years, 4, which corresponds to the age incadence of the fracture itself.

DISCUSSION

For purposes of discussion the classification of delayed union falls into the following groups: 1. Comminution. 2. Compound fractures. 3. Plating. 4. The undetermined type.

NOTE.—Two of the cases of delayed union had extensive injury of the soft parts; another occurred in a man of sixty-four.

I. *Comminution.*—Simple comminution occurred in 22 cases. Of these: Time of union shortened, 1. Time of union normal, 15. Time of union delayed, 6.

Most of these fractures were reduced by manipulation under ether—or open operation—and immobilized in a plaster-of-Paris cast. Under this treatment, rapidity of union in simple, comminuted, civil fractures would seem the rare exception. There is a tendency, rather, to delayed union, though this depends somewhat upon the age of the patient, the extent of the comminution, and the trauma.

II. *Compound Fractures.*—There were 52 compound fractures with complete records in this entire series: Of these, 34 showed delayed union, and 5 non-union, divided as follows:

1. Uncomplicated		13
a. Normal union	9 (70%)	
b. Delayed union	4 (30%)	
2. Comminuted fractures		39
a. Normal union	4 (10%)	
b. Delayed union	30 (77%)	
c. Non-union	5 (13%)	

NOTE.—Osteomyelitis resulted in twelve of the thirty cases of compound comminuted fractures which showed delayed union, and in all five cases of non-union.

These figures bear out what is very commonly understood, *i.e.*, that an open wound with fresh fracture, indicating more or less laceration of the soft tissues, evidently exerts a marked tendency to delayed union—3 out of every 10 cases—(30 per cent.). When accompanied by comminution, which usually implies an extensive trauma or crush, delay union will occur in three out of every four cases, and non-union in one out of every eight.

Osteomyelitis, it is evident, plays a major rôle in the prolongation of the normal time of union. It is rarely acute but usually a local chronic form resulting from necrosis of one or more fragments of bone which have become non-viable and act as sequestra or foreign bodies, with the resultant bone cavity and sinus formation, quite similar to what has been designated by Chutro[7] in War Fractures, "Bone Fistulæ." These fragments, if small, may be extruded through the sinus, but usually require

operative removal. In addition, until these cavities have been sometime closed, measures such as bone-grafting cannot be considered for improvement of the type of union.

III. *Plating.*—Plating was assigned as a cause for delayed union in six cases of simple fracture. The following table may be of interest:

Simple fractures—25 plated	Normal union	Delayed union	Non-union
Humerus	3	0	0
Radius and ulna	6	0	0
Femur	6	2	0
Tibia	3	4	0

These cases are comparatively few and deductions from a few figures are likely to be misleading. It is to be noted that all the cases of delayed union occurred in the lower extremity; and in the tibia, in fully fifty per cent. A factor that must be considered, however, is that in three of the tibia and one of the femur cases, previous attempts at non-operative reduction had been made, and open operation undertaken only when these had failed—as late as the third and fourth week after injury. It is well recognized that to disturb bone repair at this time will delay union. It would therefore seem that plating in itself is accountable for delayed union in relatively few cases of simple fracture—possibly 8 per cent. of the cases in which it has been used.

IV. *The Undetermined Type.*—This group includes those cases in which delayed union occurred for no obvious reason. Jones [8] has described a type of fracture in the tibia of young children which he considered most refractory. There are also cases he mentions that apparently for several weeks show no sign of callus formation or evidence of bony repair in spite of accurate reduction. Then suddenly the dormant reparatory processes are awakened, and union will occur fairly rapidly. We have not observed any of the cases of the first type, but there has been an occasional case in which no sign of repair can be detected in the usual normal period required for union, and which eventually unites effectually. With the idea that there may be in these cases a disturbance of calcium metabolism, or insufficient calcium in the blood, calcium lactate has been administered in one or two instances, with, however, no appreciable effect. A study of metabolism in fractures might serve to throw some light upon this obscure group, and result in the elaboration of some satisfactory therapeusis. A routine Wassermann might also throw some light upon the etiology of this special class.

Late open reduction, as a cause for delayed union, may be explained away by the fact that non-operative methods of reduction were first attempted and open reduction decided upon late in the treatment. In any analysis of statistics with regard to delayed union, this group of cases will always figure. The evolution of a standardized treatment of fractures, designating more accurately those fractures which should receive early operation, will tend to reduce them to a minimum.

Multiple fractures and comminution with infection scarcely merit any consideration further than mere mention.

The cases of mal-union from incomplete reduction were all cases that had been treated inefficiently elsewhere, and referred to us after unsuccessful attempts at proper reduction had been made.

CAUSE OF NON-UNION

Non-union occurred in ten cases as follows: (*a*) Compound fracture with comminution and osteomyelitis, 5. (*b*) Fracture of the upper third of the ulna, 1. (*c*) Fracture of the neck of the femur, 4.

These have been discussed elsewhere. "Non-union would rarely occur if delayed union received proper attention." Jones.[8]

SUMMARY

Among the general causes of delayed and non-union, attention has been called to the fact that syphilis, even in the absence of history and manifestations of the disease, may be a factor in preventing normal union. A routine Wassermann would seem indicated in all cases in which delayed union might be suspected.

It will be noted that 50 per cent. of the delayed union cases, as analyzed, are due to compound or compound comminuted fractures, and a small number are found caused by comminution alone. Purposely, no fracture treated by balanced suspension and traction has been included in this study.

However, it is well known that Blake's treatment in war fractures, which these compound comminuted fractures of civil life so closely resemble, tends to produce more rapid union and return of function. It is gratifying to realize that, as the problem presents itself, there is at hand a method which should obtain improved statistics for this large recalcitrant group. Too, the small number of delayed union cases in which plating is indicated may be diminished by the increased frequency with which balanced suspension will be found applicable.

Attention has been called to a group of cases in which the cause for delayed union cannot be accurately determined, and it has been suggested that studies in metabolism may serve to explain the delay and suggest a rational therapeusis.

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THE TREATMENT OF BONE CAVITIES*

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It has been long recognized that cavities and tunnels in bone, when opening on the surface of the body, heal slowly or not at all.

Such cavities result from opening circumscribed pyogenic abscesses in long bones, from removal of local tuberculous foci, from curetting away new growths, from excision of bone cysts and in chronic hæmatogenous osteomyelitis. In infected compound fractures, especially gunshot fractures, very complicated cavities and tunnels result. The external or subperiosteal callus encloses one or more detached necrotic fragments or sequestra, and this casing of new bone is analogous to the involucrum of chronic hæmatogenous osteomyelitis.

It is well known that cavities in the soft parts heal by the gradual approximation of the walls, granulating surface coming in contact with granulating surface and uniting.

In the process of healing in a bone cavity, for example, in the end of the tibia, granulations form over the entire cavity, but the rigid bony walls do not permit the drawing together of the granulating surfaces. The skin at the margin of the cavity begins to turn in and a thin layer of epithelium dips down over the granulations. Very shallow grooves and cavities may become covered over in this way, but in larger cavities, after advancing a certain distance, the epithelium no longer grows; little new bone is formed beneath the granulating area and the cavity often remains nearly the same size year after year. Sargent[1] records a cavity three inches long from which, sixteen years before, a four-inch sequestrum had been removed.

Healing can only occur if, beneath the granulating surface, new bone or new connective tissue is formed, and thus the level of granulations is gradually raised until the cavity is filled up and the skin heals over the surface. Healing, however, rarely occurs in this way; but that it does occur occasionally is shown by the case reported by Doctor Mathews, in which a large cavity, left after curetting away a giant-cell sarcoma in the head of the tibia four years ago, is soundly healed; and yet the X-ray shows a defect in the bone still present. This cavity is undoubtedly filled with fibrous tissue, and I have recently had the opportunity of seeing a cavity, about 1 cm. in diameter and 2 cm. in depth, following osteomyelitis, soundly healed for years which was completely filled with fibrous tissue. The bone at the margin of the cavity was eburnated, but at the bottom of the cavity the tissue looked like cancellous tissue and the connective tissue plug was firmly adherent to this portion.

* Read before the New York Surgical Society, October 8, 1919.

There are many examples of healing after this manner shown in the bone cavities produced in animals for experimental purposes. It must be remembered that for sound healing restoration of the bone is not essential; a bone cavity may be filled with fibrous tissue. But in the great majority of large bone cavities, especially those following traumatic osteomyelitis, the cavity will not fill up and healing does not occur, and the surgical treatment of the cavity is as important as the removal of foci of infected bone or the extraction of a sequestrum. Renfrew J. White [2] suggests that the reason lies in the lessened vascularity due to the duration of the reparative process, the stage of cicatricial contraction having set in; osteosclerotic changes progressively denser, thicker and less vascular limiting cell proliferation. Sargent suggests that the full maturity of the new-formed fibrous tissue has been reached. But in many instances there is little or no osteosclerosis. I have seen unhealed bone cavities at the lower end of the tibia in which osseous tissue making up the walls was soft, vascular and easily scraped away, even after the cavity had remained open for years. Moreover, in chronic bone abscesses (Brodie's) there is much osteosclerosis, yet if the abscess is opened, the soft parts heal over the bone satisfactorily. May it not be that environmental conditions, such as the desiccation and irritation of granulations by the air, contact with dressings, solutions, surface bacteria, dirt, etc., are unfavorable for such exuberant growths and such elaborate repair as would be necessary for the replacing of large bone defects? A condition of repair and interference with repair is reached analogous to ulceration in the soft parts.

It has been long recognized that the most satisfactory method of dealing with a cavity with rigid walls is the removal of such portions of the bony wall as will permit the soft parts to come in contact easily with the remaining underlying bone; the replacement of an unyielding wall by a yielding wall. This means usually the conversion of the cavity into an open gutter. It presupposes complete removal of all foci of osteitis and every morsel of necrotic tissue or sequestrum. It means, in many instances, a most formidable and extensive operation.

In Cases IV, V, VI, and VII, I have shown examples of this method of treatment. It is the treatment recommended recently by Broca, by Chalier,[3] by Sargent and by Renfrew White.

However, in bone cavities in close proximity to a joint, the removal of the roof and side walls, with the idea of allowing the soft parts to fall in, may be almost impossible or necessitates a very difficult flap or plastic operation with damage to sound tissue. Moreover, in certain tunnels following compound fractures, the removal of all the bone on one side of the tunnel leaves the shaft very weak and with poor mechanical support (Fig. 1). To be sure, there is ample evidence of the extraordinary power of bone regeneration in young subjects after the removal of large portions of the shaft, and even evidence of formation of bone from connective

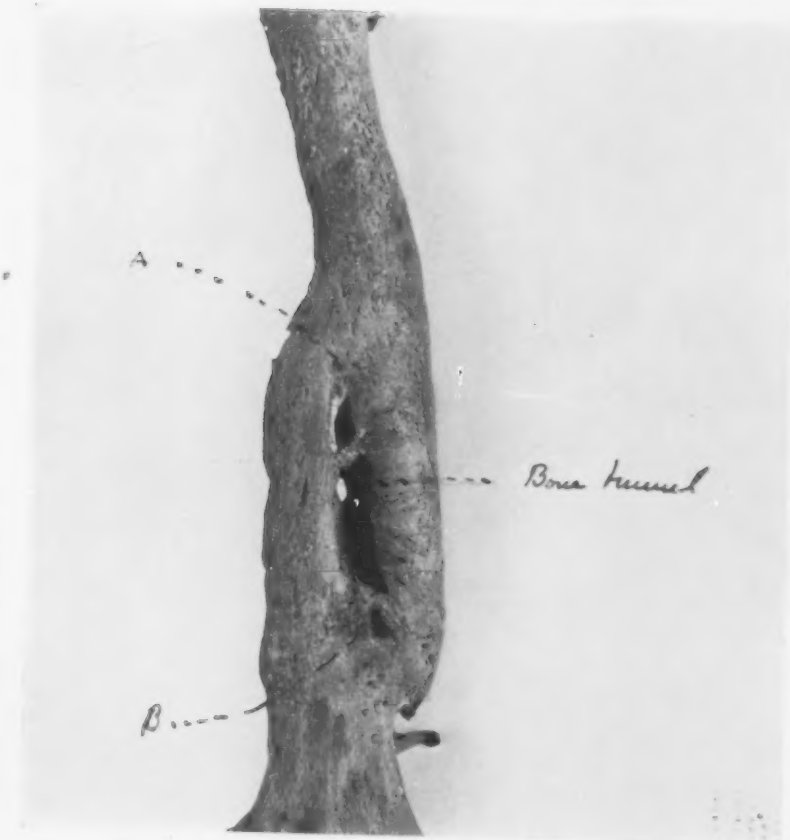

FIG. 1.—Old compound fracture of femur, showing bone tunnel. *A B* shows how bone would be weakened by excision.

tissue, apart from any osteoperiostic activity. But it is to be remembered that infection has, in many of these cases, impaired the osteogenetic properties of the cells; nor do we yet know what are the conditions favorable for the transformation of connective tissue into bony tissue, for creating

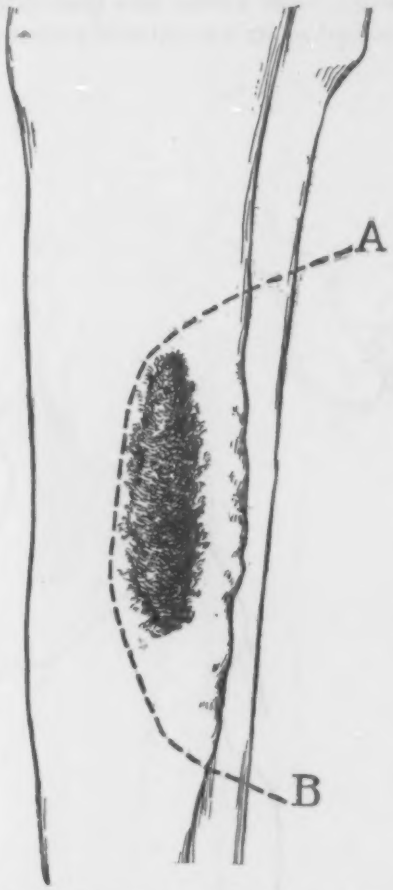

FIG. 2.—(Case IV.) Outline drawing from X-ray plate of tibia. *A B*, line of excised bone. Dark area represents bone cavity.

what Leriche [4] calls the "milieu ossifiable." Nor do we know the conditions causing exhaustion of the reparative process.

For these reasons I wish to call attention to some of the other methods of closing bone cavities. For the last fifty years there have been numerous attempts to secure healing by plugging the cavity rather than by obliterating it. Many substances have been used, such as gypsum, copper amalgam, gutta percha, various cements, bismuth paste and absorbable materials, such as sterilized pieces of sponge, rolled-up catgut, starch and iodoform, decalcified bone chips, etc. None of these methods produced results sufficiently satisfactory to lead to their general use. In 1903 Mosetig-Moorhof published a number of cases in which bone cavi-

ties had been closed satisfactorily by a plug made of iodoform, spermaceti and sesame oil. He developed a very elaborate technic. The bone cavity was most carefully prepared with chisel and electrically driven burrs and saws, the walls being cut away until smooth, sound bone was reached on all sides. The cavity was then dried by a blast of hot air and finally the warmed plugging material poured in, every care being

FIG. 3.—(Case VI.) Outline drawing from X-ray plate of femur. *A B* shows line of excision. Shaded area shows diseased bone.

taken to fill completely the excavation. After the material hardened the soft parts were accurately sutured.

In the cases where the soft parts healed, it was found by X-ray examination that the bone defect gradually grew smaller and that the plug was slowly absorbed. In 1904 Silbermark [5] reported a number of experiments on animals in which he had introduced the Mosetig mixture into cavities made in the metatarsal bones of dogs. He found that the material was absorbed and the defect gradually filled with new bone.

Since then there have been many satisfactory results published in which this method was used; but the technic is complicated, the sterilization of the plugging material not without difficulties, and in many instances fistulæ form from which is discharged the oily part of the mixture and granules of iodoform and spermaceti. These fistulæ easily become infected. My own experience is limited to its use in cavities following

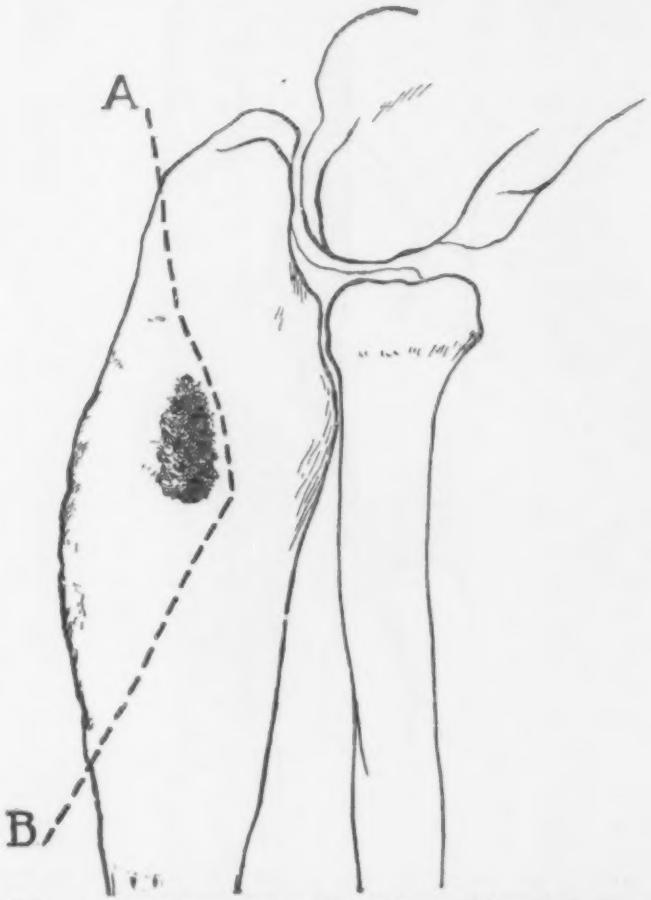

FIG. 4.—(Case VII.) Outline drawing from X-ray plate of ulna. *A B*, line of excised bone. Shaded area shows bone cavity.

bone tuberculosis. I have had one case of severe iodoform poisoning following resection of the hip, a case reported in this society ten years ago. In this case, however, dry iodoform powder was used.

It has long been known that in local suppuration in bone—a condition usually described as Brodie's bone abscess—if the cavity is exposed and one of the walls cut away so that there is no overhanging roof left, the soft parts can be brought together and the skin sutured. The cavity fills with blood which is gradually replaced with new-formed tissue. The

microörganisms have not sufficient virulence to infect the blood clot—Cases I, II, III, etc. This was the method of treatment recommended by Watson Cheyne [6] twenty or more years ago and it is to-day the most satisfactory treatment for small, chronic, localized abscesses surrounded by eburnated bone. In these cases it is unnecessary to carry out an

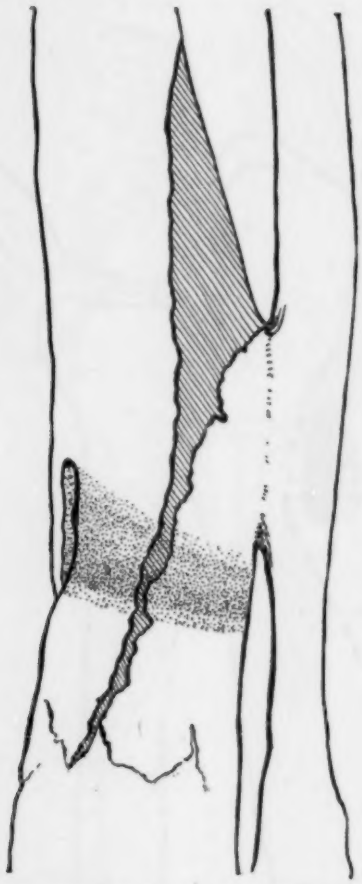

FIG. 5.—(Case VIII.) Outline drawing from X-ray plate of tibia. Dotted area shows tunnel in tibia Shaded area shows line of old fracture and new bone.

extensive removal of the bone with the idea of obliterating the cavity, nor is it necessary to fill the cavity with fat, fragments of muscle or plugging of any kind. Long experience gained since Brodie first lectured on this interesting condition, seventy-three years ago, has shown that the soft parts will heal soundly after the evacuation of the abscess.

If a blood clot remains uninfected it furnishes an excellent medium for regeneration of new connective tissue and bone, and Schede's method of filling tissue defects with an aseptic blood clot is based on this fact. We are all familiar with the growth of new bone into the blood clot after a

simple fracture and many of us have followed Bier's [7] suggestion of injecting blood in ununited fractures to promote osteogenesis. Bancroft,[8] with the idea of studying repair in bone cavities, made excavations in the diaphysis of the humerus in dogs. Every effort was made to secure hæmostasis, but after the soft parts were closed the bone cavities regu-

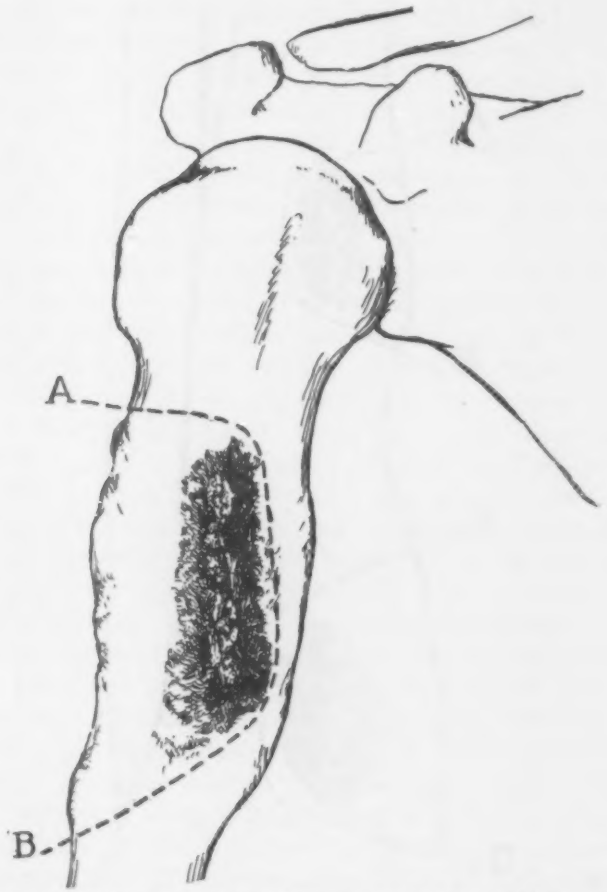

FIG. 6.—(Case IX.) Outline from X-ray plate of humerus. *AB*, line of excised bone. Shaded area shows bone cavity.

larly filled with blood. At the end of twelve days there was evidence of the early formation of new bone. In animals killed after four months it was difficult to detect the site of bone cavity. New bone had completely replaced the blood-filled excavation.

But blood clot is readily infected. Dorst has shown that the susceptibility is increased forty-fold for the staphylococcus if a hæmatoma be present. Furthermore, skin sutured over a collection of blood does not heal satisfactorily, even if there is no infection. In running the finger over certain scars ten days or two weeks after an operation defects are

sometimes felt where there has been a collection of blood due to failure of exact hæmostasis. At these places the skin is generally thinned as if the blood had forced apart the corium and underlying connective tissue to a certain extent, preventing exact apposition. For these reasons, a bone cavity of considerable size will almost certainly not heal if allowed to fill

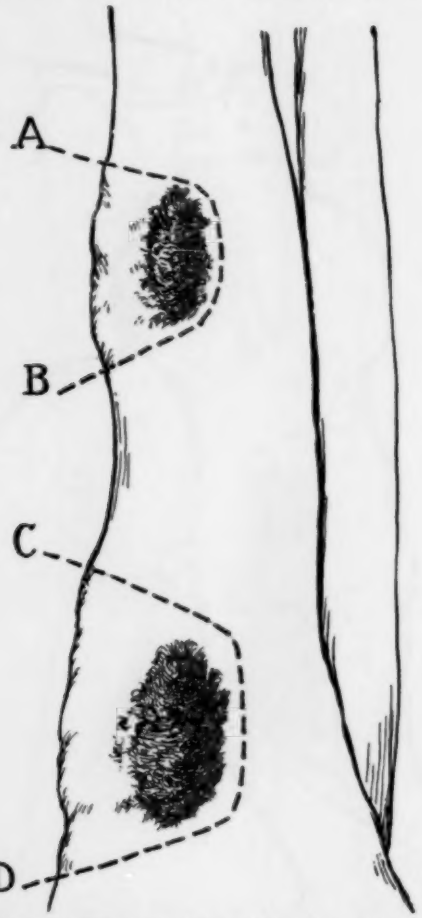

FIG. 7.—(Case X.) Outline drawing from X-ray plate of tibia. *A B* and *C D*, lines of incision in bone. Dark area represents bone cavity.

with blood and the soft parts closed, even if the cavity is apparently sterile.

Although Neuber, in 1893, reported a number of cases of patients in which free fat had been transplanted successfully in the soft parts to fill defects, it was not until ten years later that Chaput reported four cases in which he had successfully plugged bone cavities following osteomyelitis with fat. Since then twenty-one cases have been reported in France, twenty-four in Germany, one in Italy and four recently by Rutherford Morison in England. Makkas,[9] in 1912, reported a number of experiments in which he had transplanted fat into cavities made in the lower ex-

tremities of the femur of dogs. In one of the large animals the cavity made was said to be the size of an egg, and in one the cavity was cut through into the joint so that the fat plug was placed in a bone tunnel, one end of which projected into the articular cavity. The fat mass was taken, in each instance, from the hypogastric region of the same animal. In seven out of eight experiments he secured sound healing. He killed the animals at periods varying from one month to three months. In the majority of the animals the fat plugs had been replaced by a gelatinous connective tissue. In one, curiously enough the one in which the fat had been transplanted for the longest time, the plug was still composed of normal fat. In each instance apparently an osteoplastic layer was in contact with the fat graft and the cavity seemed to have grown smaller. In the dog in which the fat perforated the articular cavity, there was no sign of joint irritation or joint adhesion. Calforio,[30] in March, 1918, reported the result of small fat transplants in cavities made in the upper extremity of the tibia in rabbits. From these experiments he concluded, first, that the fat did not remain as such in the bone, and second, that it was completely substituted by new-formed osteoid tissue.

X-ray observation of the fat transplanted in bone in man shows apparently similar results; in some instances little or very little replacement by bone, in others, as shown in Figs. 12, 13 and 14 of Morison's article, almost complete replacement of fat by bone in a few months. In Case VIII of this series the cavity, examined two years after the fat transplant, is still apparently not filled with bone. We have, then, in fat a material which has been proven, both experimentally and by actual practice, suitable for plugging bone cavities. It has certain obvious advantages: It does not readily support bacterial life, nor does it readily undergo decomposition. I have here a mass of human fat, removed last August and exposed to the dust and air in an open window. The mass has shrunken somewhat, has hardened a little and become a darker color on the outside. There is a slight odor resembling that of butyric acid. A second piece I have put in tap water in an open, wide-mouthed bottle for ten days. It presents no material alteration, but there is a very faintly disagreeable odor and the water is cloudy. Moreover, when fat is broken down by the enzymes of bacteria it probably splits into fatty acids or their salts (soaps) and glycerine. Neither are especially harmful to the tissue. Further, there is no tissue in the body that undergoes normally such frequent change, the cells under varying conditions of nutrition losing or gaining their fat content. In other words, fat seems to be easily taken up by the body cells and from the body cells, for the fat cell, after all, is only a connective tissue cell in which the accumulation of fat in the cytoplasm has reduced the cell to little more than a vesicle surrounding the fat. The fibrillar connective tissue which follows the blood-vessels and holds the mass together is very scant. Again, fat presents a material which has physical properties suitable for healing of the overlying skin,

for the subcutaneous areolar tissue normally contains fat. For the success of the transplant the bone cavity must be carefully prepared. If the wall is not everywhere made up of sound bone, if there is a tiny morsel of necrotic bone, foreign body or area of osteitis, the result will almost certainly fail. I have followed the plan, during the last three years, of doing a two-stage operation in all bone cases, first laying open the bone cavity, removing the sequestra, area of osteitis and smoothing off the walls. Then for ten days to three weeks flushing the cavity systematically with Dakin's solution, following the Carrel technic. Finally, when the cultures show no organism present but the staphylococcus, and these only one in two or three fields in smears, the second operation of closure of the soft parts is attempted. In nearly every instance I have, during this period of treatment, removed a small particle of dead bone overlooked or detached at the first operation.

When it is decided from the nature of the cavity or tunnel that a fat transplant is suitable, the skin is excised about the margin of the cavity and freed from the underlying tissue until its edges can be brought together. Exact hæmostasis of the soft parts is essential, the fat itself serving as a plug to help stay the hemorrhage from the bony walls. The fat is then excised, a piece being taken that is distinctly larger than the cavity. I have used the subcutaneous fat from the abdominal wall in each instance. In Cases IX and X the patients were lean young men with a scant fatty layer and the fat pad was thin. This fat is thrust into the cavity, the end of graft mushrooming through the opening in the bone. The skin is then closed over the graft by interrupted sutures. In every instance this has been the most difficult part of the operation. In each of the patients there had been several previous operations, so that the skin was found bound down to the bone and soft parts by cicatrices. In no instance have I been able to get very accurate skin approximation, portions of fat protruding in the intervals between the skin sutures. In one instance the skin was undermined for half the circumference of the leg. Parallel freeing incisions would have aided in this case the sliding over of the skin. The wounds have not been drained. After dressing with sterilized gauze a light plaster bandage has been applied. In no case was there a rise of temperature. The dressing was removed on the eighth day.

In Case VIII there was a small dark crust made up of dried blood and protruding fat. This fell off at the end of three weeks; the epithelium had healed beneath it. In Case IX a portion of the skin parted on removing the sutures and part of the fat sloughed. There was no rise of temperature or sign of infection, and it was soundly healed in three months. In Case X two cavities were filled with fat. One healed. In the second cavity there was a slight separation of the skin over a distance of five mm. At this point there was a small slough when last seen, two months after the operation.

In treating infected bone cavities the following conclusions may be drawn:

1. That complete removal of all the infected bone lining the cavity, of all foreign bodies and of every particle of dead bone is essential.

2. That in the great majority of cases the cavity must be obliterated to insure healing.

3. That this is most satisfactorily accomplished by the removal of sufficient portions of the wall of the cavity to allow the soft parts to fall in and fill it up.

4. That in certain tunnels and cavities near joints some form of plugging may be indicated.

5. That of the many materials used as plugs the free fat transplants present real advantages.

6. That the two-stage operation, with careful sterilization of the cavity under bacteriological control, following the Carrel-Dakin technic, is of great value.

7. That in the small chronic bone abscesses in the ends of long bones with attenuated infection no filling or intermediate sterilization is necessary.

CASE RECORDS

CASE I. (*Chronic Suppurative Osteomyelitis*—Brodie's Bone Abscess—Bacillus Typhosis).—W. F., aged sixty-five years. Admitted St. Luke's Hospital December 15, 1912. Discharged January 17, 1913, cured.

Present History.—Slight pain for three weeks over lower end of tibia, then intense pain and tenderness for several days.

Previous History.—Typhoid fever forty-four years ago. About a year later began to have pain in leg. An incision made in skin from which pus escaped, sinus persisting fourteen years. After sequestrum one inch long removed, leg healed and remained healed and painless for thirty years.

Physical Examination.—Over lower end of tibia bone enlarged, intensely painful on pressure at one point. X-ray shows great thickening of bone; shadow too dense to show bone cavity.

Operation.—Sclerotic bone chiseled away, abscess evacuated, wound sutured. Primary union. Pure culture of typhoid bacillus obtained from pus. Widal negative. Seen four months ago. Leg still soundly healed six years after operation. Shown at New York Surgical Society March 28, 1917.

CASE II. (*Chronic Suppurative Osteomyelitis of Tibia*—Brodie's Bone Abscess—Staphylococcus Aureus).—I. L., aged twenty-seven years. Admitted St. Luke's Hospital December 7, 1915. Discharged January 7, 1916.

Previous History.—Nineteen years before admission had periostitis in both tibias. Occasionally since then small sequestra have been discharged. No persistent sinus.

Present Illness.—Three weeks ago he developed pain in the left

leg with slight swelling above the ankle. No trauma. Intense pain, worse at night, in lower part of leg. Tender on pressure.

Operation.—Sclerotic bone removed with chisel, pus evacuated from cavity size of cherry; skin sutured, no drainage. Seen two years after operation. Bone still soundly healed. Shown at New York Surgical Society March 28, 1917.

CASE III. (*Chronic Suppurative Osteomyelitis of Right Tibia*—Brodie's Bone Abscess).—F. P., aged thirty-one years. Admitted St. Luke's Hospital February 1, 1917. Discharged March 30, 1917.

Present Illness.—Four weeks before admission sudden onset of pain and swelling of right leg below knee. No history of trauma.

Previous History.—Negative.

Operation.—Sclerotic bone removed with chisel. Pus evacuated; packing for twenty-four hours. Secondary suture; primary union. Soundly healed one year later. Shown at New York Surgical Society March 28, 1917.

CASE IV. (*Chronic Suppurative Osteomyelitis of Right Tibia*).—Mrs. H. T., aged forty-seven years. Admitted St. Luke's Hospital February 23, 1910. Discharged March 25, 1910.

Present Illness.—Seven weeks before admission struck right leg. Since then has been unable to walk and has had a slight purulent discharge from an old sinus in the middle of right tibia.

Previous History.—When fourteen months old had osteomyelitis of right arm and leg. Incision by Doctor Buck. Arm healed, but from time to time she has had discharge from the right tibia and attacks of severe pain.

Operation.—February 26, 1910. Tibia exposed, necrotic bone removed. No careful effort to approximate soft parts.

Readmitted September 11, 1918. Six years later. Sinus has persisted and she has had intense pain in leg from time to time since last operation.

First Operation.—September 24, 1918. Resection of anterior and internal wall of abscess cavity and removal of bone until sound bone was reached on all sides of excavation. Carrel-Dakin treatment for one month.

Second Operation.—October 24, 1918. Closure of soft parts. Four weeks later small pocket of pus under skin in soft parts. Incision. Healed two weeks later. Soundly healed, free from disability eleven months after operation. Shown before New York Surgical Society October 8, 1919.

CASE V. (*Chronic Suppurative Osteomyelitis of the Femur*).—Dr. R. G., aged forty-five years. Admitted St. Luke's Hospital June 27, 1916. Discharged October 9, 1917. Operation three months previously for chronic suppurative osteomyelitis. Has had a persistent sinus opening on inner side of thigh. Several operations for drainage were performed during the summer and autumn of 1916. During this period secondary pockets formed in the popliteal space and to the outer side of the thigh. Leg became flexed on the thigh. In July, 1917, the whole wound tract was laid open, sinuses were ex-

cised, cortical portion of the femur chiseled away and two small sequestra were removed, leaving a comparatively smooth bony gutter into which the soft parts could be crowded. The wound closed very slowly, the two folds of soft tissue turning in against the bone. The knee gradually regained its mobility. The wound has been soundly healed for one year. Shown before New York Surgical Society October 8, 1919.

CASE VI. (*Chronic Suppurative Osteomyelitis of Right Femur*).—T. E., aged thirty years. Admitted St. Luke's Hospital January 22, 1919. Discharged March 24, 1919.

Present Illness.—For last sixteen months discharging sinus in right thigh.

Previous History.—Fifteen years ago had an attack of pain in right thigh. Thigh was opened, sinus persisted for a few months, then remained closed for eleven years. Four years ago sinus again opened, was curetted and remained healed until present attack. No disturbance of function.

Physical Examination.—Shows a long scar extending from the greater trochanter down the outside of the thigh. In the centre of the scar is a sinus communicating with the femur.

First Operation.—January 28, 1919. Four sinuses extending between gluteal muscles excised, external part of greater trochanter chiseled away. Carrel-Dakin treatment instituted.

Second Operation.—February 13, 1919. Edges of wound excised and wound closed by interrupted sutures. Primary union. Seen one week ago. Leg soundly healed. Has developed tuberculosis of the lungs.

CASE VII. (*Tuberculous Osteomyelitis of Right Ulna with Secondary Pyogenic Infection*).—L. G., aged eleven years. Admitted St. Luke's Hospital December 7, 1918. Discharged July 15, 1919.

Present History.—Sinus leading to bare bone has been repeatedly curetted in the Out-Patient Department, but discharging sinus still persists. X-ray examination shows much thickness of ulna with a distinct cavity.

First Operation.—Sinus excised, subperiosteal resection of the upper part of ulna forming the inferior wall of the bone cavity.

Second Operation.—Five weeks later. Closure of the soft parts. Healed. Has since developed a tuberculous abscess of anterior surface of forearm.

CASE VIII. (*Chronic Suppurative Osteomyelitis of the Tibia*).—Ensign W. T., aged twenty-two years.

Previous History.—Fell from cliff in 1913, sustaining a compound fracture which became infected. Has had eight operations for removal of sequestra and for drainage. Wound would heal and then break open. In December, 1917, sinus again opened. X-ray showed union of old fracture of tibia and fibula with deformity and with a tunnel through the junction of tibial fracture.

First Operation.—Excision of skin about sinus and removal of

sides of tunnel until sound bone reached. Two small sequestra also removed. Carrel-Dakin treatment.

Second Operation.—Skin edges excised. Free fat transplant taken from subcutaneous fat of abdominal wall and placed in bone tunnel. Skin approximated by interrupted sutures. Healed. Shown before New York Surgical Society October 8, 1919.

CASE IX. (*Chronic Suppurative Osteomyelitis of Humerus Following Gunshot Injury*).—E. B., aged twenty-one years. Admitted St. Luke's Hospital February 28, 1919. Discharged May 5, 1919.

Present Illness.—On September 29, 1918, was wounded with a piece of shrapnel in the upper part of right humerus. Discharging sinus ever since.

Physical Examination.—Shows a wound on the antero-external aspect of the upper part of right arm. Wound of exit on posterior surface of arm. There is still a discharge of pus from the external one.

First Operation.—March 11, 1919. Wall chiseled away from one side of bone cavity and ten sequestra removed. Dakin treatment instituted until smears showed one staphylococcus per field. Streptococci absent.

Second Operation.—April 8, 1919. Removing side walls to make gutter of bone cavity more shallow.

Third Operation.—April 24, 1919. Piece of fat 10 cm. by 5 cm. transplanted from abdominal wall to cavity. Skin edges freed and sutured. Difficulty in approximating edges; scar tissue on outer side unyielding.

Clinical Notes.—Sutures removed eighth day. Upper part of wound separated exposing fat graft. Exposed graft at the end of several weeks looked like a whitish slough extruding small droplets of oily material. At the end of two months a small slough separated and was removed. During this time there was a distinct rancid odor about the wound and the epithelium at its margins was macerated. At no time was there any temperature nor evidences of pyogenic infection. Wound healed July 25, 1919. Shown before New York Surgical Society October 8, 1919.

CASE X. (*Chronic Suppurative Osteomyelitis of Left Tibia*).—F. K., aged twenty-seven years. Admitted St. Luke's Hospital December 10, 1918. Discharged March 27, 1919.

Previous History.—Five years before admission developed osteomyelitis of left tibia following injury at football. Sinus persisted for two years and then remained healed for three years.

Present Illness.—Four months ago old wound broke down. Three operations curetting bone. Still has discharging sinus.

First Operation.—January 17, 1919. Cortex of bone was removed from the anterior portion of the lower part of the tibia. Two cavities exposed; one containing pus and connected with sinus, other cavity filled with granulations.

Second Operation.—January 23, 1919. Skin edges freed. Two

fat pads transplanted from the abdominal wall to fill in both bone cavities. Skin closed with interrupted sutures.

March 27, 1919. Patient discharged; wound healed, except for small portion of fat exposed in lower wound about size of head of a pin. Patient left for Australia and has not been heard from.

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THE TREATMENT OF CENTRAL LUXATION OF THE FEMUR*

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This paper is practically limited to the consideration of fracture of the base of the acetabulum with penetration of the femoral head, uncomplicated by extensive fracture of the pelvis or injury of its contents; in other words, to the class of cases in which the chief concern is the functional result as affected by treatment.

The cause of the injury is usually direct force applied to the trochanter, the immediate penetration being increased possibly in some instances by subsequent weight bearing.

The physical signs, although sufficiently distinctive, are often overlooked at the time of the accident.

The prominence of the trochanter is lost. The limb is somewhat flexed, adducted, and slightly shortened. There is a fair range of flexion and extension, but rotation is very limited, and abduction is almost completely restricted because of the contact of the trochanter with the acetabular rim. There are usually sensitiveness and other evidences of local bruising of the tissues, and movements of the limb are painful, but as there are no evident signs of fracture the injury often passes as a contusion.

When weight bearing is attempted, pain is increased and is reflected down the inner and posterior region of the thigh, caused apparently by pressure on the nerves passing in the neighborhood of the displaced femoral head.

The persistence of pain, stiffness and limp leads to further investigation, and the diagnosis is finally established by X-ray examination weeks or months after the injury. In this connection I may note that many years ago I was present at an operation for supposed pelvic tumor which disclosed the head of the femur, the previous history of injury and the physical signs of the displacement having escaped the attention of the surgeon.

In my experience, at least, there has been no opportunity for immediate treatment, nor does it appear that the methods usually employed when the diagnosis has been made have been successful in permanently reducing the displacement.

These are forcible manipulations under anæsthesia or the application of traction, either longitudinal or combined with a lateral pull. In the first instance the displacement, if reduced, usually recurs when the limb is placed in the normal attitude, while traction is not often effective in withdrawing the head from the pelvis.

The final results are reported as fairly satisfactory, probably as com-

* Read before the New York Surgical Society, November 26, 1919.

pared with those of fracture of the neck of the femur. It may be assumed that after a time accommodative changes will relieve the pressure on the nerves and increase the mobility of the new articulation, but the restriction of abduction must persist, and consequently insecurity, apparent shortening and limp. The practical indication in treatment, therefore, is to assure a sufficient range of abduction, which from the functional standpoint is of far greater importance than the reduction of the dislocation, although the one is necessarily dependent on the other. This may be accomplished by the abduction method as applied for fracture of the neck of the femur, although the mechanism is quite different.

Under normal conditions the trochanter is apposed to the upper border of the acetabulum only at the limit of abduction, and in the treat-

DIAGRAM TO ILLUSTRATE THE MECHANISM OF THE ABDUCTION METHOD

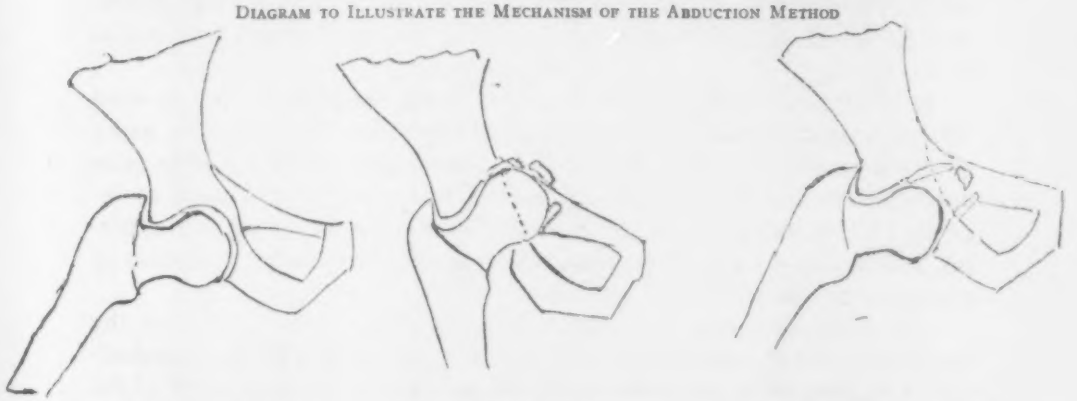

FIG. 1.—Contact of the trochanter and pelvis at the limit of normal abduction.

FIG. 2.—Contact of the trochanter and pelvis in central luxation restricting abduction.

FIG. 3.—Reduction of the displacement by the abduction method.

ment of a fracture it is desirable that the limb should be fixed in the degree of abduction that establishes such contact (Fig. 1).

In this instance the head of the femur having been driven inward, the trochanter is apposed to the acetabular rim when the limb is in the line of the body (Fig. 2). This furnishes a point of resistance or fulcrum against which the leverage of the extended limb may be utilized to withdraw the head of the femur from the pelvis (Fig. 3).

The patient, having been anæsthetized, is placed on a pelvic support, provided with a perineal bar, the two extended limbs being supported by assistants, who draw the patient firmly against the perineal bar. The sound limb is then abducted to the normal limit to fix the pelvis. The other limb in the extended attitude and under manual traction is then gradually and forcibly abducted, if practicable, to the normal limit, which should indicate the complete withdrawal of the head from the pelvis, and in this attitude a plaster spica is applied extending from the line of the nipples to the knee.

It is possible, if the patient were treated soon after the injury, that the displaced acetabular floor might be reduced somewhat by pressure

through the vagina or rectum, but in the cases that I have seen, the lapse of time has made this impracticable, and in most instances one must depend upon the gradual obliteration of the cavity by natural processes to prevent redisplacement. The plaster spica must be retained, therefore, with this end in view for several months, locomotion being permitted as soon as it does not increase the discomfort, since displacement is impossible in the abducted attitude. After the support is removed, the limb must be passively abducted to the full limit at frequent intervals, until the patient has regained voluntary control of this movement.

This treatment is designed primarily for uncomplicated cases, in which natural mechanics may be utilized. If the pelvis were so fractured that effective leverage could not be employed because of the lack of a resistant fulcrum, one would attempt to secure a sufficient degree of abduction by direct manual traction combined with gentle lateral movement of the limb.

It is possible, also, if the opportunity for immediate treatment were offered, that the head might be disengaged by direct manipulation, as by pressure on the knee after flexing and adducting the thigh. Under ordinary conditions, however, the accommodative changes will have so increased the resistance, that this manipulation is not likely to be successful, and in any event disengagement is merely preliminary to fixation in extension and abduction.

The range of abduction is dependent upon the distance between the trochanter and the acetabular rim, and it is determined by their apposition. Complete abduction indicates, therefore, complete disengagement of the head; and a limited range a corresponding incompleteness of reduction.

If the resistance has become so great that the head cannot be withdrawn by natural leverage, an osteotomy below the trochanter is indicated, since the purpose of treatment is to secure and to retain a sufficient range of abduction for functional requirements.

Intrapelvic exploration would seem to be a doubtful expedient. In recent cases the displacement should be easily reduced by the abduction method, while if of long standing the prospect of improved function would hardly justify the risk.

The following case, which has served as the text for this paper, is one of six that have come directly or indirectly to my notice, indicating that the injury is not adequately represented by statistics.

> The patient, a man of thirty-five years of age, was injured by the overturning of an automobile on September 28, 1918. He was taken to a hospital and after examination was discharged with a diagnosis of contusions. He remained in bed for about three weeks, suffering from stiffness and pain in the right hip and thigh, which was increased by weight bearing. Seven weeks later he came to the Hospital for Ruptured and Crippled, walking with the aid of a cane, presenting the physical signs typical of the injury, as illustrated by

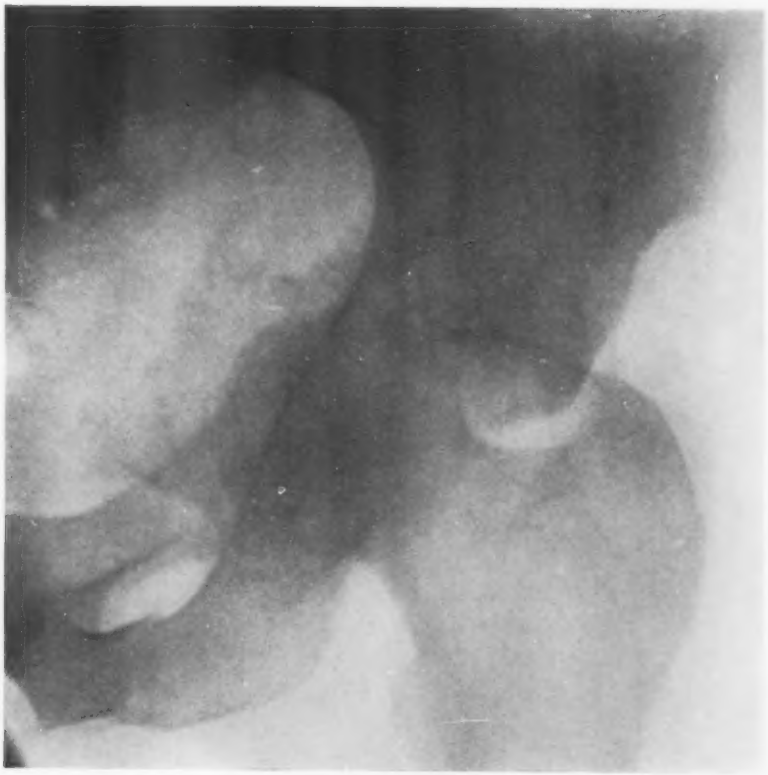

FIG. 4.—Showing contact of the trochanter and acetabular rim limiting abduction.

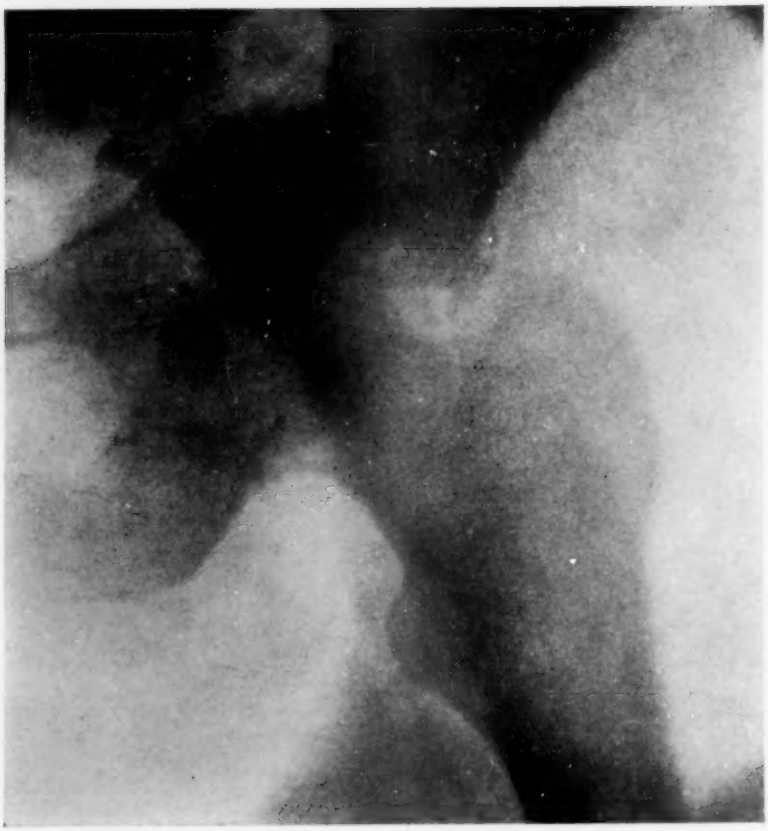

FIG. 5.—After reduction by the abduction method. Taken through the plaster spica.

FIG. 6.—One year later, showing the obliteration of the cavity. The reduction of the displacement, though incomplete, has increased the range of abduction from 0° to 30°, which is sufficient for functional use.

the accompanying X-ray picture (Fig. 4), which shows also a fracture of the ischium. He was admitted to the hospital and with some force the limb was abducted nearly to the normal limit (Fig. 5). The pain was immediately relieved, and he soon began to walk about without discomfort. Seven weeks later the plaster support was removed tentatively, but unfortunately the patient was obliged to return to his work to the neglect of after-treatment, and was not seen again until July. At this time the limb was somewhat flexed, slightly adducted and motion was much restricted. There was, however, but little discomfort on use. He was again admitted to the hospital and the operation was repeated, the abduction being forced to about 40 degrees. The plaster spica was removed at the end of ten weeks and the limb could then be abducted to 30 degrees (Fig. 6). He has returned to the hospital for stretching at intervals and in spite of the lack of other accessories of after care he retains a sufficient range of abduction for functional requirements and has but little discomfort and but slight limp.

It is apparent that if a sufficient range of abduction is attained by the manipulation, its retention can be assured by fixing the limb for a sufficient time to permit the accommodative changes in the tissues. This time should vary, therefore, with the duration of the displacement, and the quality of the after-treatment at command, and fixation should again be employed if the range of abduction progressively lessens. It is evident, therefore, that in the case described this period was far too short, although it might have been sufficient if the reduction had been accomplished immediately after the injury.

This latest application of the principles of the abduction treatment illustrates its wide range of practical adaptability. Nearly all the so-called disabling contusions about the hip are in reality fractures of the femur or of the pelvis, and either because of uncorrected deformity or as an instinctive adaptation to weakness and pain, the limb usually becomes flexed and adducted.

In all obscure injuries in this region, therefore, the abduction method might be applied with advantage as for fracture of the neck of the femur, since it is the only efficient means of adjusting and fixing the fragments if this is broken, while if the pelvis is injured, restraint of the limb is required for effective splinting. The abduction treatment has the further advantage that immediate correction of deformity, the first essential of success, is supplemented by an after care conducted with a definite aim and guided by physical signs that indicate the progress of reconstruction upon which functional recovery depends.

GUNSHOT FRACTURES OF THE TI IA AND FIBULA*

OBSERVATIONS ON THE PATHOLOGY AND TREATMENT

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American Red Cross Military Hospital No. 2 was located in Paris and generally functioned as a base hospital. However, during June, July, and August, 1918, with heavy fighting in the region of Château-Thierry, some 65 kilometres away, the hospital acted almost continuously as an evacuation hospital. At such times cases were received as early as twenty-four hours after having been wounded and without other treatment having been done than their first-aid dressings. At other times the cases were received on an average of from three to four days after the injury and after they had been submitted to an operation at field or evacuation hospitals. In view of the necessity of making room for incoming wounded during the rush periods, it was necessary to evacuate cases as rapidly as possible to hospitals further back. While an effort was always made to hold fracture cases until union was well under way, it was often unavoidable to evacuate them a few days after admission. As compared to ununited fractures of other long bones, those of the tibia and fibula seemed, perhaps best of all, to stand early transportation. Accordingly, the records of gunshot fractures of the tibia and fibula show considerable variation as to the duration of the stay of the patient in the hospital.

Colonel Blake[1] has said: "Fractures of both bones tend to overlap and also to interlock in bad positions, and are often difficult to reduce; moreover, repair in the leg seems more indolent than elsewhere in the body, and these fractures sometimes unite very slowly and imperfectly. The lack of soft parts over the tibia possibly accounts for some of such cases of delayed union, sluggishly granulating wounds and disagreeable scars." In view of the difficulty that may be encountered in the treatment of cases of this kind, it may not be amiss to make a few remarks on the cases at this hospital.

At American Red Cross Military Hospital No. 2, from November 1, 1917, to about January 1, 1919, there were treated 43 gunshot fractures of the tibia alone, 26 of both the tibia and the fibula, and 17 of the fibula alone—86 in all.

As an introduction to an analysis of these cases, a résumé of the anatomy of the leg may not be inappropriate. According to Davis,[2] the muscles are divided into four groups: (*a*) The extensor group, including

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* Authority to publish granted by Board of Publication, S. G. O.

[1] Col. Jos. A. Blake: "Gunshot Fractures of the Extremities," p. 92. Masson & Cie, Editeurs, Paris, 1918.

[2] Davis: "Applied Anatomy."

the tibialis anterior, extensor longus digitorum, and the extensor longus hallucis; (*b*) the flexor group, including the tibialis posterior, flexor longus digitorum, and the flexor longus hallucis; (*c*) abductor group, including the peroneus longus, peroneus brevis, and peroneus tertius; (*d*) calf muscles, including the gastrocnemius, soleus, and plantaris. The tibia and fibula are connected by (*a*) the anterior and posterior superior tibio-fibular ligaments, (*b*) the interosseous membrane, (*c*) the anterior and posterior interosseous ligaments. The main nerves to be considered are three, the internal popliteal nerve, the anterior tibial nerve, and the musculocutaneous nerve, the two latter being branches of the external popliteal nerve. The internal popliteal nerve supplies the gastrocnemius, soleus, plantaris, and popliteus, and gives rise to the posterior tibial nerve. The latter extends downward in a sheath shared by the posterior vessels, between the superficial and deep muscles of the posterior portion of the leg. The posterior tibial nerve supplies the tibialis posticus, the soleus, the flexor longus hallucis, and the flexor longus digitorum.[3] The anterior tibial nerve, which arises from the external popliteal nerve, originates below the head of the fibula in the interval between the peroneus longus and the fibula. After winding externally around the head of the fibula, beneath the peroneus longus, extensor proprius hallucis and the extensor longus digitorum it reaches the anterior aspect of the leg. Lying on the anterior surface of the interosseous membrane, it joins the anterior tibial vessels 8 to 12 cm. below its origin and accompanies these vessels down the leg as far as the ankle. It supplies the tibialis anticus, the extensor longus digitorum, the extensor proprius hallucis, and the peroneus tertius. The musculocutaneous nerve continues the course and direction of the external popliteal. Descending through the leg in a fascial tube in the septum between the peroneal muscles and the extensor longus digitorum, it becomes superficial by piercing the deep fascia anterior to the fibula in the lower third of the leg. It supplies the peroneus longus and the peroneus brevis.

There are three main arteries, the anterior tibial, the posterior tibial, and the peroneal arteries. The line of the anterior tibial artery may be taken just internal to the head of the fibula to a point on the front of the ankle midway between the malleoli. The anterior tibial artery pierces the interosseous membrane, but the anterior tibial nerve winds around the head of the fibula and joins the artery 5 to 7 cm. or more down its outer side. The line of the posterior tibial artery is from the middle of the popliteal space to the middle of the line joining the internal malleolus and the internal tuberosity of the calcaneus. The peroneal artery is given off from the posterior tibial 2.5 cm. below the edge of the popliteus muscle. It follows the inner edge of the fibula beneath or in the fibres of origin of the flexor longus hallucis.

Davis [3] calls attention to the fact that when the fibula is broken above

[3] Piersol: "Anatomy."

its lower fourth, there is usually little displacement because the attached muscles hold it in place. In a fracture of the tibia, the displacement of the lower fragment is backward, upward, and slightly outward. It is produced mainly by the muscles of the calf pulling on the tendo calcaneus (Achilles). The upper fragment is pulled forward by the quadriceps femoris.

There are no laws governing gunshot fractures. The types or varie-

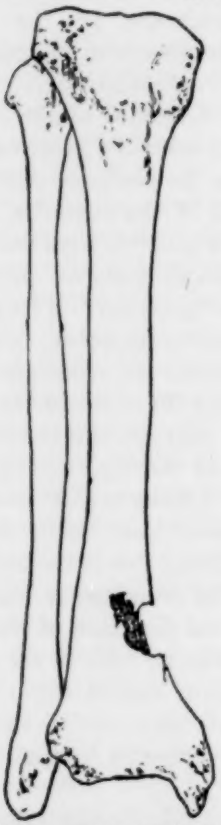

FIG. 1. — Incomplete fracture of the tibia, "bone wound" type, deep antero-posterior groove.

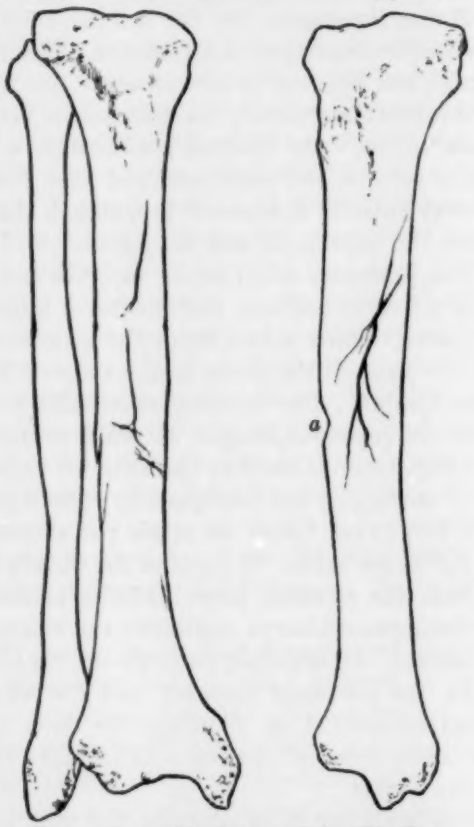

FIG. 2.—Incomplete fracture of the tibia illustrating a bone "wound" at *a*, and extensive fissuring.

ties of damage which may be caused to the bone are innumerable. The injuries vary according to the type of missile, its velocity, and its direction in relation to the bones. An excellent general classification is that of Frost,[4] who, in his excellent paper on compound diaphyseal fractures, divides them into: 1. Contusions (lesions essentially periosteal). 2. Incomplete fractures, consisting of (*a*) grooves, (*b*) fissures, (*c*) penetrations, (*d*) perforations. 3. Complete fractures.

Considering the tibia and fibula as a group, there is the natural further classification of fractures of both bones and either of the two bones separately. Frost has shown an example in his article of an X-ray

[4] Frost, Harold: *Military Surgeon*, March, 1918.

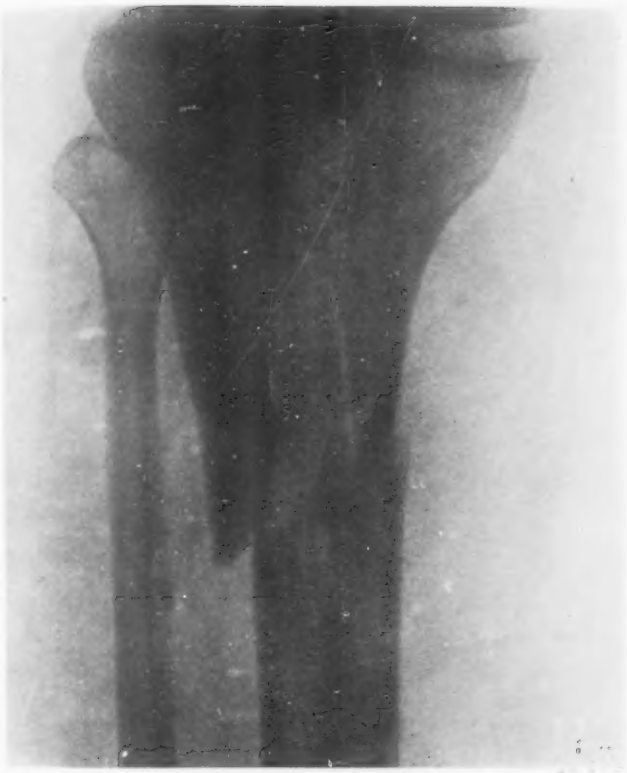

FIG. 6.—Complete fracture of the tibia.

demonstrating a contusion of bone, but the X-ray in question would be classed by the writer as a "bone wound," a subdivision of incomplete fractures. Moreover, it does not seem possible to admit of contusions being shown in the X-ray, and for the sake of classification, it will be considered that all gunshot lesions of bone that are visible on the X-ray plate must necessarily fall under either incomplete or complete fractures.

FIG. 3. — Incomplete fracture of the tibia, of the fissure type, extending into the knee-joint.

FIG. 4.—Complete fracture of the tibia. Perforating type.

FIG. 5.—Complete fracture of the tibia with considerable comminution.

Fig. 1 shows an example of the "bone wound" type of fracture. It is an incomplete fracture which takes the form of a deep antero-posterior groove. (Case: Favier, Theophile, 269th Inf., French Army. Wounded May 23, 1917. Removal of bone fragments on the same day. Admitted to American Red Cross Military Hospital No. 2, June 10, 1917, with a circular plaster cast having a window. Discharged October 16, 1917.) Fig. 2 illustrates two types of incomplete fracture, as it shows a small bone wound at (*a*) in the lateral view, and also an extensive fissured fracture, which does not, however, involve the entire shaft and thus cause a complete fracture. (Case: Frye, Horace F., Corporal, 6th Marines. Wounded October 7, 1918. Débridement done at front-line hospital. Admitted to American Red Cross Military Hospital No. 2 October 9, 1918. The leg was put in a posterior gutter splint and was not suspended. There was beginning union 15 days after wounding and consolidation at 22 days. No traction.

Evacuated as Class "C" 43 days after his injury.) Fig. 3 shows an incomplete fracture of the fissure type which extends into the knee-joint. (Case: Walsh, William J., Corporal, 307th Inf. Wounded September 2, 1918. Diagnosis: Gunshot wound of left knee-joint with compound fracture of the head of the left tibia. Admitted to American Red Cross Military Hospital No. 2 September 6, 1918. Evacuated September 8, 1918.) It must be remembered that, as all gunshot fractures are compound, in those which communicate with the knee-joint the latter is almost sure to be involved. An incomplete

FIG. 7.—Complete fracture of the tibia and fibula with comminution.

FIG. 8. — Complete fracture of tibia and fibula from which the bone fragments have been removed at operation.

FIG. 9. — Complete fracture of the tibia with considerable loss of substance. Drawing made from an X-ray taken three days after operation.

fracture of the penetration type has been described as one in which the missile enters the bone but does not leave it. Fig. 4 shows a complete fracture of the tibia of the perforating type. (Case: Parker, Kirke, Corporal, 125th Inf. Wounded August 29, 1918. Machine-gun bullet. Clean "through and through" wound. No operation. Suspended in Hodgens splint with traction by Sinclair skate. Beginning union 14 days after injury. Patient walking with a cane 35 days after injury.) Fig. 5 is a stage beyond Fig. 4 and shows complete fracture of the tibia with considerable comminution. (Case: Turner, Benjamin R., private, 5th Marines. Wounded June 5, 1918. Evacuated July 8, 1918.) Fig. 6 shows a similar fracture but nearer the head of the tibia. (Case: Raczynski, Louis, private, 127th Inf. Admitted to American Red Cross Military Hospital No. 2 on August 8, 1918, from Field Hospital No. 127. Evacuated August 9, 1918,

to Base Hospital No. 6.) Fig. 7 shows a typical smashing complete fracture of the tibia and fibula. (Case: Rettinger, Jonas A., private, 305th Inf. Wounded September 4, 1918. Admitted to American Red Cross Military Hospital No. 2 September 6, 1918. X-ray and débridement on admission. Evacuated September 8, 1918.) Fig. 8 shows a complete fracture of the tibia and fibula from which the bone fragments have been removed. (Case: Jarvis, Daniel, private, 11th Inf. Wounded October 20, 1918. Débridement and removal of bone fragments at Mobile Hospital No. 5. Admitted to Ameri-

FIG. 10.— Complete fracture of the fibula with 4 cm. loss of substance. This case was not operated upon.

FIG. 11.—Complete fracture of the fibula with extensive comminution.

can Red Cross Military Hospital No. 2 October 27, 1918. Suspended in a Hodgens splint. Beginning union 26 days after wounding. Evacuated as Class "D" 30 days after injury with very little union and with the wound still discharging.) Fig. 9 is a good example of a gunshot fracture with extensive loss of substance. (Case: Palmer, Earl H., 2nd Engineers. Wounded June 7, 1918. Admitted to American Red Cross Military Hospital No. 2 June 8, 1918. Operation the same day. Date of the X-ray from which this drawing was made, June 11, 1918. Evacuated July 19, 1918.) Fig. 10 shows a gunshot fracture of the fibula with 4 cm. loss of substance. (Case: Bailey, Samuel, private, 311th Inf. Wounded October 25, 1918. Admitted to American Red Cross Military Hospital No. 2 October 29, 1918. No operation. Discharged as Class "D" November 4, 1918.) Fig. 11 shows a fracture of the fibula with extensive comminution. (Case: Boyer, Edgar L., 143rd Inf. Wounded October 17, 1918. Machine-

gun bullet. No operation. Admitted to American Red Cross Military Hospital No. 5 October 21, 1918, where he remained until November 26, 1918, when he was transferred to American Red Cross Military Hospital No. 2. Patient is able to walk with a cane on January 9, 1919.) Fig. 12 shows a fracture of the fibula with loss of substance. (Case: Thornton, George, private, 107th Field Artillery. Admitted to American Red Cross Military Hospital No. 2 on September 1, 1918, from Evacuation Hospital No. 4. Discharged September 5, 1918, to Blois.) In Fig. 13 there is a comminuted fracture of the fibula, upper third. (Case: Pt. Merlog.) We have the record of one case of gunshot fracture of both fibulæ. (Case: Powell, Clyde R., private, 109th Inf. Wounded September 16, 1918. X-ray examination shows about 3.5 cm. loss of substance in both fibulæ. Wounds practically healed on November 18, 1918.) Another case shows fractures of tibiæ. (Case: Cruickshank, Lewis F., private, 125th Inf. Admitted to American Red Cross Military Hospital No. 2 September 2, 1918, from Evacuation Hospital No. 5. Antero-posterior X-ray plates of both tibiæ show oblique fractures of the middle third in good position.)

Treatment.—The principles of first-aid in the gunshot fractures of the tibia and fibula are the same as in those of other fractures. The first consideration is the control of hemorrhage, by tourniquet, pressure in or above the wound, or clamping of the vessels, according to the facilities. The danger of leaving a tourniquet on too long (a good rule is not longer than half an hour) has so often been demonstrated that it is unnecessary to do more than mention it. Of next importance is the immobilization of the fracture. This is not a very difficult problem in the case of the tibia and fibula. The most satisfactory arrangement is the Thomas splint with traction applied in such a manner as will not unduly constrict the ankle, as a well-padded gaiter, bandaged on, or a double loop or hitch. In the absence of a Thomas splint the fractures of the tibia and fibula may very satisfactorily be immobilized in some form of posterior splint, as the posterior wire splint, the tin "gutter" splint, or the wire Cabot splint. A long enough splint should be used so that it extends well above the knee-joint. A liberal application of iodine in the wound and about its edges, as an antiseptic, seems to be above reproach. The first-aid is completed with the addition of a sterile gauze dressing, and a prophylactic injection of tetanus antitoxin.

After the first-aid treatment, the patient should be evacuated as rapidly as possible to a field, evacuation, or mobile hospital for operative treatment. Before any operation is attempted, it is of the utmost importance that the patient shall have recovered from shock. If such is not the case, all efforts should first be made to revive the patient. The usual methods of operation on war wounds are applicable to fractures of the tibia and fibula. A careful débridement of the wound, with the complete removal of all foreign bodies, pieces of clothing, necrotic and ragged tissues should be practiced. Effort should be made to preserve as much as is possible of the periosteum, and bone fragments with periosteal attachment should not be removed. The best disposition to make of bone fragments without periosteal attachment is a matter which still permits some debate. By the majority of surgeons they are considered as foreign

FIG. 12.—Complete fracture of the fibula with loss of substance.

FIG. 13.—Complete fracture of the upper third of the fibula, with comminution.

bodies and accordingly removed. Should the leg already have become infected by the organisms of gas gangrene, a much wider débridement or muscle excision will be necessary or even the amputation of the limb. The débridements must be carefully done with avoidance of injury to the nerves and the larger vessels. It is especially desirable to preserve the posterior tibial artery. The wound is left wide open and lightly packed with dry gauze. The early employment of Dakin solution is to be recommended.

After the patient has arrived at the base hospital or such other hospital where he is liable to remain for some time, measures for the further treatment of the fracture should at once be instituted. For gunshot fractures of both the tibia and fibula, or for the tibia alone, treatment by suspension and traction is the method of choice. In fractures of the fibula alone, immobilization in metal or moulded plaster splints is sufficient. A Balkan frame with the trolley pulley block is the most convenient manner of suspending the splint. Of the latter, several have been employed, *viz.*, the Hodgens, the Blake, the full and half ring Thomas. The author prefers the half ring Thomas splint (bent at the knee to about 140 degrees), for by using it in connection with the double pulley system, to be described later, counter traction may be established without the necessity of the inconvenient upper traction rope which crosses the patient's face. The leg is supported in the splint by the well-known bands fastened by clips. Some of these bands may be removed to facilitate the dressing. By adjustment of the bands in accordance with the information given by the portable X-ray machine, the proper anteroposterior alignment may be obtained.

The method of applying the traction must be such as to best fulfill the following conditions: (1) The attachment must be low down on the foot, so as to avoid wounds of the soft parts which may extend down that far. (2) The attachment must be such as not to constrict the foot or ankle. (3) It must not be painful. (4) It must be capable of maintaining such outward rotation, dorsal flexion, and inversion of the foot as is desired. (5) It must not slip or become disarranged while in use. Several devices have been evolved to overcome these obstacles. By far the most satisfactory instrument, in the opinion of the writer, is the " skate " devised by Major M. Sinclair, R. A. M. C. This skate has been described by Colonel Blake and his associate, Captain Bulkley,[5] as follows: " It consists of a block of wood a little longer than the foot and very slightly wider, in the free edge of which are cut about ten notches. Its centre contains a longitudinal slit through which passes a bolt provided with a thumb nut on the exposed side. The side of the board toward the foot is padded with cotton and covered with gauze. The transverse bar shown in the draw-

[5] Blake, Col. Jos. A., and Bulkley, Captain Kenneth: " Treatment of Fractures of the Extremities by Means of Suspension and Traction." *Surgery, Gynæcology and Obstetrics*, March, 1918.

ing is a piece of iron 5 millimetres thick, 2 centimetres wide, and 15 centimetres long, with a hole at the centre and at each end. With glue 8 or 10 narrow tapes are pasted along each side of the foot, each tape having previously had attached at the end toward the sole a small curtain ring. The bands over the dorsum of the foot do not meet in the midline, but leave a free area to prevent constriction and interference with the circulation. The foot is fastened to the board by lacing the rings on each side to each other on the under surface of the board. The apparatus forms practically a ball-and-socket joint for the control of the position of the foot. The lower free edge of the transverse metal bar rests on the

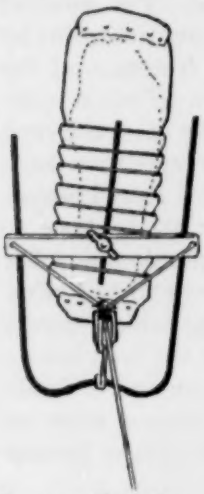

FIG. 14.— End view of "Sinclair skate" showing manner of securing outward rotation of the foot by adjustment of the transverse bar.

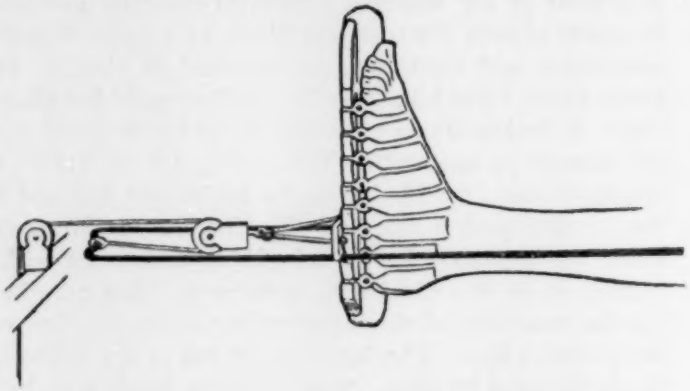

FIG. 15.—Lateral view of "Sinclair skate" and pulley, showing method of securing proper amount of dorsal flexion of the foot by adjusting the transverse bar further up or down the skate as desired, and also showing method of attaching the pulley.

parallel bars of the (Hodgens) splint and maintains the position of the foot in the position in which it is placed. To elevate or depress the foot as a whole (correct anterior or posterior angulation at the site of the fracture), the wooden block is slipped upward or downward on the transverse bar, and the thumb screw tightened. To abduct or adduct the toes (rotate the lower fragment inward or outward) the block is rotated on the transverse bar and there fixed. To evert or invert the foot as a whole (correct lateral angulation at the site of fracture) the cord leading from one extremity or the other of the transverse bar is shortened. The 'skate' is especially useful in very low fractures of both bones and in fractures involving the ankle-joint." In Figs. 14 and 15 the leading features of the proper application of the Sinclair skate may readily be seen. Fig. 14 shows how outward or inward rotation of the foot may be secured by adjustment of the transverse bar, the foot in this figure being shown in the most usual position, that of slight outward rotation. Fig. 15 shows the necessity of placing the transverse bar far

FIG. 16.—Typical example of X-ray of the leg suspended in the splint, taken by the portable X-ray machine. The outlines of the fracture are readily made out. The Carrel tubes in the wound may easily be identified as well as the side of the splint with the clamps which are used to attach the supporting bands.

FIG. 17.—Same fracture as that shown in Fig. 16, but taken one month later and without the splint. The small foreign bodies were left in place and seemed to exert no deleterious influence on the progress of the healing.

FIG. 18.—Complete fracture of the upper third of the tibia, showing different stages of callus formation. In *A* is depicted the amount of callus formation at fifty-six days after wounding, and in *B* the callus formation at eighty-four days after wounding. A small sequestrum may be seen on the mesial side in both drawings. This was removed in the course of a dressing.

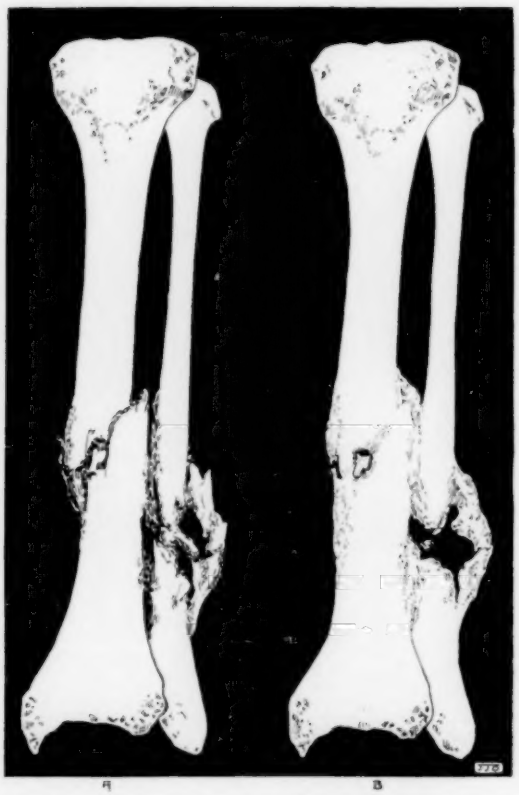

FIG. 19.—Complete fracture of the tibia and fibula with different stages of callus formation. *A* represents the condition sixty-one days after wounding, and *B* one hundred fifty-one days after wounding. At one hundred fifty-five days after operation, a sequestrum was removed from the inner border of the tibia, and a portion of the fibula around the old injury was removed. Patient was discharged forty-one days later, that is, one hundred and ninety-six days after wounding.

FIG. 20.—Complete fracture of the fibula showing callus formation.

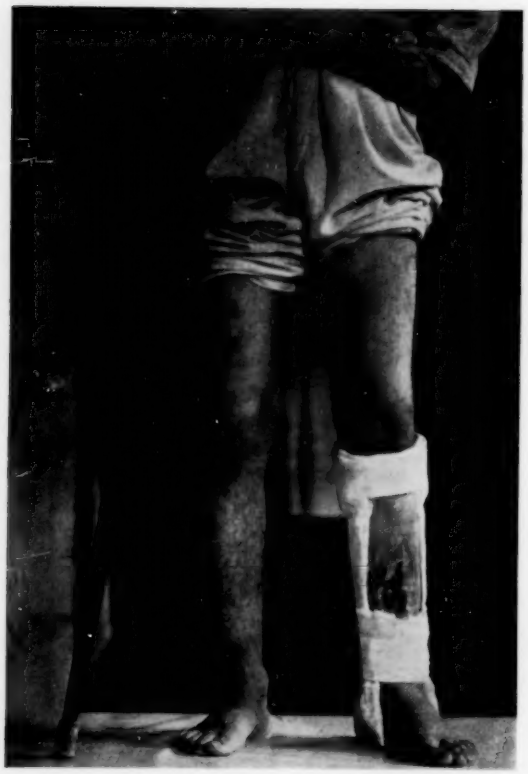

FIG. 21.—Gunshot wound of the left leg with compound fracture of the tibia showing the application of the Delbet ambulatory plaster-of-Paris splint. It will be noted that the lateral splints are extended below the inferior collar almost to the floor.

FIG. 22.—Shortening of the tendo Achillis due to traction which was applied in such a manner that the foot was held in an inadequate degree of dorsal flexion. It will be noted that, owing to the shortening of this left tendon, it is not possible to touch the left heel to the floor when both heels are abreast.

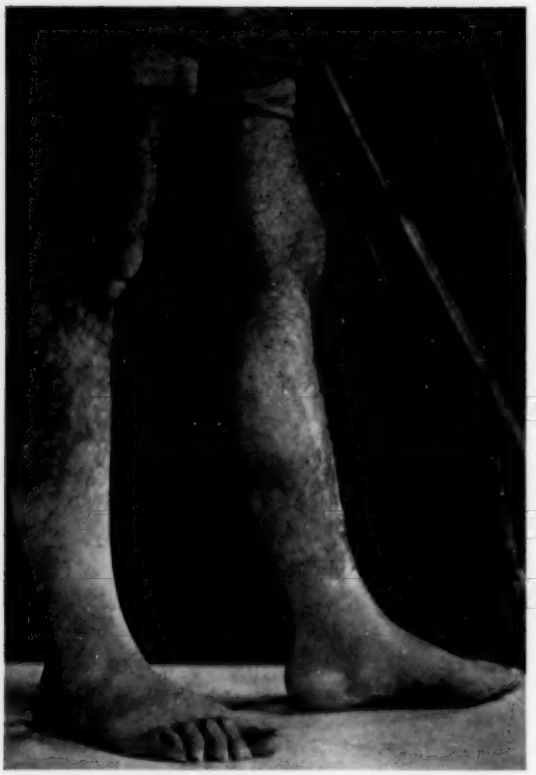

FIG. 23.—Shortening of the left tendo Achillis due to faulty application of traction. It will be noted that in order to oppose the entire plantar surface of the foot to the floor it is necessary to advance the foot.

enough back toward the heel to secure the proper amount of dorsal flexion of the foot.

The kind of glue used in fastening the bands to the foot is a matter of considerable importance. The most satisfactory seems to be that described by Major M. Sinclair.[6]

By attaching the pulley to the skate rather than to a cross bar on the frame, and by attaching the end of the rope to the splint rather than to the skate directly, in the manner shown in the figures, it is possible, with a single traction weight at the foot of the bed, to exert a pull on the foot of twice the weight, owing to the mechanical advantage of the pulley, and a pull equal to once the weight on the splint itself and in the opposite direction; that is, forcing the ring of the Thomas splint firmly against the buttock. By this pressure and the pull of the cross bands against the thighs, the requisite counter traction is secured without the disadvantage of a counter traction rope attached to the upper end of the splint and crossing in front of the patient's face to the upper opposite end of the frame.

Another method of applying traction is by means of a gaiter which laces up the front. The tendency to the formation of pressure sores on the dorsum of the foot and at the tendo Achillis, and the inability to secure the proper position of the foot, obviously are the disadvantages of this method, and moreover, it is necessary to supplement it by a foot suspension. Should it become necessary to employ a gaiter, it should be well padded underneath and bandaged securely to the foot. Where the wound is high enough on the leg, it may in some cases be possible to secure traction by bands glued to the sides of the calf or by adhesive strips. This method has the same disadvantage of inability to secure the

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[6] Major M. Sinclair, R. A. M. C., has supplied us with the following guide as to the preparation and use of the glue:

Test for the glue:
Place 4 oz. of glue in 4 lbs. of cold water and leave in a cool place for twelve hours.

If	dissolved	bad
If coherent and gelatinous weighing	8 oz.	good
If coherent and gelatinous weighing	16 oz.	very good
If coherent and gelatinous weighing	20 oz.	excellent

The following is the formula:

Very good glue	50 parts
Water	50 parts
Glycerine, or glucose calcium chloride	4 or 6 parts
Menthol	1 part

Soak for twelve hours and then melt on a water bath. Neutralize to litmus with sodium hydrate, as commercial glue at times contains free hydrochloric acid. Add 4 parts in summer, and 6 parts in winter, of glycerine or glucose calcium chloride and 1 part menthol. Frequent heating evaporates the water, which should be added from time to time. When reheated many times, adhesive power is lost.

Technic: (1) The skin is not shaved.

(2) Wash the skin with soap and hot water, which contains about 4 drams of washing soda to the pint, to convert the oil of the skin into soap, as glue will not adhere to a greasy surface.

(3) Dry the skin.

(4) Apply the warm glue evenly, brushing all the hairs of the limb in an upward direction.

(5) Keep a tension on the gauze all the time. Bring it quickly but carefully into contact with the limb (inner and outer surface), and apply a neatly and loosely woven bandage, starting a hands-breadth above the malleoli up, to the knee joint (in case of fracture of the femur).

(6) When dry apply traction.

NOTE.—The adhesive can be made waterproof with a 2 per cent. solution of potassium bichromate applied in the dark and then exposed to the light, or by means of formalin.

(7) The extension must always be very carefully applied, whether with Maw's elastic cotton net or with gauze.

(8) The extension must be changed at once if the patient complains of a tickling or burning sensation under it, but it generally requires changing about the tenth, twentieth, and fortieth days.

proper position of the foot. A fourth method, the Finochetto's band, seems to be even less advisable. In this method the traction is secured by means of a thin metal band which is passed above the os calcis and behind the tendo Achillis. The chief advantage of this arrangement is the readiness with which dorsal flexion is secured. But it possesses no advantages which are not possessed by the Sinclair skate, and in addition it exposes the patient to the risk of another portal of infection.

The amount of traction to be used is determined by the position of the fragments as shown in the X-ray. Fig. 16 shows a typical portable X-ray of the leg in a splint with Carrel tubes in the wound. Fig. 17 shows the same leg one month later. It is well to start with about 12 pounds in fractures of both bones and to reduce this amount as reduction of the fracture is effected. A smaller amount of weight is required when only the tibia is fractured. When the double pulley system of traction is employed, a weight equal to one-half the desired pull is used.

The position of the fragments is further altered and corrected by appropriate manipulation of the supporting bands of the splint. For posterior sagging in the fracture the bands in this region are tightened; for anterior bowing they are loosened. If traction alone does not secure the desired alignment, the bands on one side of the fracture may be tightened and those on the other side of the fracture may be loosened, as necessary. To facilitate access to the wound in dressing it, that band which is opposite the wound is removed. If there is a tendency to sagging at the fracture at the time the dressing is done because of the removal of the band, a small sterile band may previously have been placed next to the wound, which band is kept loose except at the times of the dressings, when it supports the fracture. Where the wound is large and there is considerable discharge, the best material of which to construct the bands is a rubberized fabric which is non-elastic, waterproof, and may readily be cleaned. Such bands may contain perforations and are best fastened to the splint by means of metal spring clips. Where it is unnecessary to change the bands frequently, flannel ones may be used and these are best fastened to the splint by safety pins. A convenient arrangement is to make the band long enough to reach from one side of the splint to the other and back again, in which case it will be necessary to fasten it only on one side.

The treatment of the soft parts is in itself a very wide field and one meriting the most careful consideration and study. Even assuming that the wound has been properly and thoroughly débrided at the time of the operation, it is necessary to be constantly on watch for the formation of pus pockets. With the foot held at right angles to the axis of the leg, as is the best position, a slight tension is exerted on the tendo Achillis and from there in turn upon the gastrocnemius and the soleus. A drainage tract that passes between the fibres of these muscles seems to be especially liable to have its sides approximate and cut off the exit for the pus.

Leaving a wide rubber drainage tube in such a tract for longer than forty-eight hours invites the danger of eroding a vessel wall and causing a severe hemorrhage. It may be necessary from time to time to enlarge the narrowing orifice of the tract by spreading a clamp in it. In all deep sinuses which have a tendency to pocket, it is most advisable to irrigate it daily with warm saline solution by means of a catheter attached to an irrigating can.

Irrigation of the wound by Dakin's fluid by the method of Carrel has produced very good results. Even where no secondary suture is contemplated, this method of treatment cleans up the wound very quickly. The muscle tissue takes on the well-known bright red appearance, and all particles of necrotic tissue disappear. As long as there is bone presenting in the wound it seems inadvisable to attempt a secondary suture even though the bacteriological reports are satisfactory. When the wounds become shallow and are cleanly granulating, the success attendant upon drawing the skin edges together by means of adhesive straps is very remarkable. Wounds 5 by 12 cm. or smaller are far more simply treated by this method and with less inconvenience to the patient and with less trouble to the surgeon.

There are no set rules for the length of time that the leg is to be suspended. In general, it may be said that the leg should not be taken down until the union is firm. In cases where it is particularly desirable to get the patient up and around in a wheel chair, a properly shaped and padded posterior wire splint may be put on even if the union is not quite stiff enough to warrant discarding all splints. The methods of testing the extent of union are two, manipulation and the X-ray. In the former, the leg must be lifted free of the splint, and grasped on either side of the fracture. By gentle motion it is endeavored then to find out how much, if any, motion there is at the site of the fracture, how readily this motion may be elicited, and how painful it is. A very simple test is to grasp the leg by the ankle and gently lift it out of the splint. Examinations made by the portable X-ray machine, or better, stereoscopic X-ray plates, will give a very good conception of the extent of callus formation, but in a last analysis, the best test for the strength of the leg is the clinical one.

Figs. 18 and 19 are reproductions of drawings made from X-ray plates and show the progress of callus formation during one month (Rice) and three months (Cathery), respectively. (Cases: Fig. 18. Rice, Willard, private, 23rd Inf. Admitted to American Red Cross Military Hospital No. 2 on November 26, 1918, 54 days after wounding. Complete fracture of upper third of right tibia. In "A" is depicted the amount of callus formation in the fracture at 56 days after wounding, and in "B" the callus at 84 days after wounding. A small sequestrum may be seen on the mesial side in both drawings. This was removed in the course of a dressing. Patient evacuated January 10, 1919. Fig. 19. Cathery, Antoine, 215 Reg. d'Inf. 15 Cie., French Army. The patient was wounded on August 16, 1917, and admitted to American Red Cross Military Hospital No. 2 on September 10, 1917. On admission a tube was found inserted anteroposteriorly through the lateral aspect of the lower left leg just above the joint. X-ray examination at this time showed a comminuted fracture of the tibia and fibula with

several loose fragments in the soft tissues on the external aspect. The leg was suspended in a Hodgens splint and traction was applied by a Sinclair skate. There was beginning union in the fracture 37 days after wounding and consolidation at 57 days. Following this the convalescence was somewhat prolonged. At 64 days the leg was put in a plaster cast and at 87 days the cast was removed and the patient instructed to walk without support. At 94 days after the injury all wounds were healed, save for a scab. At 97 and 135 days sequestrectomies were done. On January 18, 1918, one sequestrum was removed from the inner border of the tibia and also a portion of the fibula about the old injury. (Col. Blake.) The patient was discharged on February 28, 1918, 196 days after wounding. "A" represents the condition 61 days after wounding and "B" 151 days after wounding.) Fig. 20 is an illustration of callus formation in a fracture of the fibula. (Case: Lynch, Donald B., mechanic, 168th Inf. Admitted to American Red Cross Military Hospital No. 2 on November 26, 1918, from American Red Cross Military Hospital No. 5. Evacuated January 10, 1919.)

Naturally, the time for repair depends entirely upon the extent of bone injury. A "through and through" machine-gun bullet wound in which the bone is merely fissured, and in which it is unnecessary to perform a débridement, will unite very quickly. On the other hand, where there is extensive loss of substance, and a large suppurating wound, the time required may be very great. Tables A and B well illustrate this variation in time. They also demonstrate the difficulty there has been to obtain consistent and complete records. It is of interest to note in Table A that the average length of time after wounding before the cases

TABLE A

18 Selected Cases of Gunshot Fractures of the Tibia

(Cases in which the records were the most complete.)

Days after injury, received at A.R.C.M.H. No. 2	Type of splint on arrival	Type of splint used for suspension	Type of traction	Beginning union at (days)	Consolidation (days)	No. days treated at A.R.C.M.H. No. 2
1	Gutter.....	Hodgens...	Skate.....	14	35	35
8	.....	Hodgens...	Strips to leg	..	..	55
2	½r Thomas	Hodgens...	Boot.....	..	..	26
3	Posterior wire	Posterior splint	.....	..	..	37
2	Wire.....	Hodgens...	.....	..	..	22
2	Wire.....	Thomas....	Skate.....	..	..	38
2	Wire.....	Hodgens...	.....	15	..	20
1	Gutter.....	Hodgens...	Skate.....	..	43	68
7	Posterior wire	Hodgens...	.....	25	..	30
1	Gutter.....	Hodgens...	.....	..	..	38
3	Posterior wire	Hodgens...	.....	23	..	24
3	Posterior wire	Hodgens...	.....	16	23	31
2	.....	Hodgens...	.....	..	..	50
4	½r Thomas	Thomas....	Skate.....	31	..	59
1	Wire.....	Hodgens...	.....	..	..	41
3	Wire.....	Hodgens...	Skate.....	45	..	69
3	.....	.....	Skate.....	..	..	50
2	Posterior wire	Posterior gutter	.....	15	22	43
Av. 2.7						

TABLE B

14 SELECTED CASES OF GUNSHOT FRACTURES OF THE TIBIA AND FIBULA (BOTH BONES)

(Cases in which the records were the most complete.)

Days after injury, received at A.R.C.M.H. No. 2	Type of splint on arrival	Type of splint used for suspension	Type of traction	Beginning union at (days)	Consolidation (days)	No. days treated at A.R.C.M.H. No. 2
4	Thomas....	Thomas....	Skate.....	..	..	31
5	Thomas....	Hodgens...	.....	36	..	36
6	Thomas....	.....	.....	30	52	59
5	Thomas....	Blake.....	.....	..	..	20
4	Thomas....	Hodgens...	Skate.....	..	..	23
3	.....	Hodgens...	Anklet.....	..	..	71
2	.....	Blake.....	Skate.....	48	..	72
4	Wire.....	Hodgens...	Skate.....	..	..	22
3	Thomas....	Hodgens...	Skate.....	..	..	30
6	Thomas....	½r Thomas	Skate.....	..	..	26
3	Thomas....	½r Thomas	Skate.....	..	..	18
4	Thomas....	Thomas....	Skate.....	..	..	17
7	Thomas....	Hodgens...	Strips to leg	..	..	51
4	Thomas....	Hodgens...	Boot.....	50	..	67
Av. 4.2						

in this series were received at American Red Cross Military Hospital No. 2 was 2.7 days, with variations from one to eight. In Table B, of fractures of both bones of the leg, the corresponding average was 4.2 days. The table also shows that the Hodgens was the splint most frequently used for suspension, and that the Sinclair skate was the device most frequently employed in the application of traction.

After there is firm fibrous union in the fracture, consolidation may be hastened by the application of the moulded plaster splint of Delbet. Some skill is prerequisite to the putting on of these splints. The essential feature of their construction lies in two lateral splint bridges which connect firm collars just above the malleoli and below the tuberosity of the tibia and the head of the fibula. These collars must be snugly approximated to the skin, which previously has been protected with vaseline. With a successful splint of this type the patient may walk without pain or injury at the site of the fracture, for the weight of the body is transmitted directly from the malleoli to the head of the tibia and fibula by means of the lateral splints. The very small amount of weight that is put on the fracture seems to accelerate the new bone formation. With this type of splint it is important that the leg be carefully observed for symptoms of pressure on the anterior tibial nerve at the head of the fibula (foot drop). Fig. 21 illustrates a Delbet splint.

Motion in the joints should be initiated as soon as possible. With most of the devices in which the traction is applied to the foot, it is not possible to get a great amount of motion at the ankle-joint while there is traction on the leg. As soon as there is union, passive, and, particularly, active motion, and massage must be started at once. Gunshot frac-

tures of the tibia and fibula are far less difficult to treat than those of the femur, and the results are generally excellent. However, it is important to bear in mind during the treatment that a cause of functional disability is the failure to preserve the proper axis for weight bearing and the lateral tilting of the ankle.[7] As soon as there is consolidation, it is important to get the patient out of bed and up in a wheel chair or walking on crutches. He should be encouraged to eat heartily and to be out of doors as much as possible.

Complications and Sequelæ.—Of first importance as a complication of gunshot fractures of the tibia and fibula must be placed gas gangrene. Practically all the war wounds are contaminated with the organisms of gas gangrene at the time of the injury. Gas gangrene may develop in cases where there has been too great a delay between the wounding and the operation, and in cases where the original débridement was inadequately performed. However, a wound that has been properly débrided may be so tightly bandaged that there is insufficient opportunity for gas drainage from the tissues adjacent to it. In such a contingency, a case of clinical gas gangrene may develop which otherwise would never have appeared. We should be on guard for the development of gas gangrene not only in cases which have not already been operated upon, but also in wounds that have been operated. While a fully developed case of gas gangrene presents a very typical picture, the *early* diagnosis of this infection is by no means easy. The factors of chief importance are the history of a recent wound, swelling of the leg, tympanitic note on percussion of the leg, the increase in the pulse rate, the odor of the wound, the maintained intelligence of the patient, the tense elastic resistance of the leg on palpation, and occasionally the X-ray plate.[8]

The most successful treatment of gas gangrene is surgical and varies according to the extent of the involvement. With circumscribed and local infections, a muscle débridement or excision may suffice. Where the gas has ruptured the muscle sheaths and has spread throughout the limb, the only hope lies in immediate amputation. The therapeutic use of serums has not given encouraging results with us, though it must be admitted that it was often not tried until surgical measures were despaired of.

Sequestra are one of the most common complications of gunshot fractures of the tibia and fibula, and they arise either from fragments of bone that were not removed at the original operation, and have died owing to their isolation from blood supply, or from ends of bone that have died because of the impairment or removal of their supply of nutrition. The diagnosis of sequestra is most accurately made by means of stereoscopic X-ray plates. In these, the fragment of dead bone is conspicuous by the denser shadow which it casts (see Fig. 18, inner margin).

[7] Dachtler, H. W.: *American Journal of Röntgenology*, October, 1918.

[8] Christopher, Frederick: "The Early Diagnosis of Gas Gangrene." *Journal of the American Medical Association*, February 8, 1918.

The stereoscopic effect gives us very definite information as to whether the sequestrum is anterior or posterior. Other evidence as to the existence of sequestra are persistent discharging sinuses, or delayed union. Not infrequently a sequestrum is found during a dressing and may be removed by a hæmostat. It may be added that in such a case it is advisable to give as a routine 1000 units of tetanus antitoxin (*vide* Government memorandum). Generally the removal of sequestra requires a general anæsthetic and an operative enlargement of the wound so that the fracture and the sequestrum are in full view before an attempt is made to remove the latter. A sequestrectomy may prove to be a very difficult and tedious operation, and great care should be exercised in the performance of it. Occasionally the bone may be refractured in the course of such an operation, and in such cases of fracture of the callus, the rapidity with which union recurs is surprising.

The knee-joint may be involved by progressive infection from wounds adjacent to it. Or it may be involved directly in the cases of fissured fractures which enter into the capsule (see Fig. 3). Or again, the knee-joint may accidentally become infected through operative procedures. In all cases knee-joint infections, especially those due to the hæmolytic streptococcus, are most unwelcome and dangerous sequelæ. Sufficient drainage of such a joint may exist through the communication to the wound, but frequently it is necessary to make lateral slits in the capsule for further drainage, and, in extreme cases, amputation at or above the knee-joint must be resorted to.

Abscesses of bone (an abscess of bone is shown in Fig. 18) and muscle are generally not alarming complications and readily may be diagnosed and treated. Gently exploring the recesses of the wound with a Kelly clamp will often locate pus pockets which have been suspected owing to a rise in the temperature curve.

Delayed union and non-union are not very frequent complications in the gunshot fractures of the tibia and fibula. These may be due to sequestrum formation, in which case the remedy is the operative removal of the sequestrum or sequestra; they may be due to foreign bodies, where, as in the case of sequestra, the treatment is the removal; they may be due to the interposition of muscle between the fragments, where surgical treatment again becomes necessary. Extensive loss of substance is often difficult to cope with and it requires long continued treatment to bridge the gap by new bone formation. Generally speaking, it is unwise to attempt bone grafts or bone splints until the wounds have completely healed. However, it may be said that a septic field is not positive assurance of the failure of a healthy bone transplant. Osteomyelitis is an infrequent, but may be a very serious complication. Its treatment is the operative removal of the infected bone, and, in the more serious cases, amputation. It seems to occur less frequently in the tibia and fibula than in the femur. Faulty position is generally the result of

the neglect of the points of treatment outlined above, but in the event of its occurrence to such an extent as to cause functional disability, refracture is occasionally advisable.

Plantar flexion is a very annoying and inexcusable complication. It is caused by fixation of the foot in the splint in insufficient dorsal flexion, which causes a temporary shortening of the tendo Achillis and the muscles attached to it. When the patient is able to bear his weight on the fracture, he finds that, with the leg straight down, the ball of the foot only touches the floor (see Figs. 22 and 23, Pvt. N. Bosson, French Army, FCC Tibia, seventy-fourth day), and efforts to press the heel down to the floor are quite painful. The treatment of this condition is massage and persistent employment of exercises which tend to stretch the tendo Achillis and its attached muscles. At the time of the original injury or at a succeeding operation, one of the main nerve trunks may have been injured, which one being readily ascertained by a study of the type of paralysis. If the motor function is not improved or recovered by three or four months after the injury, and the wound is entirely healed, a neurorrhaphy is indicated. Stiff joints, except those due to infection, are generally of very temporary duration and most always yield quickly to massage. The presence of blisters is to be suspected when the patient complains of a tickling or burning sensation under the glued straps. The skin should at once be inspected in such a case, and in the event of blisters being present, another type of traction should temporarily be substituted.

The writer wishes to express his thanks to Colonel Joseph A. Blake, M.C., Chief Consultant in Surgery for the District of Paris, whose teachings have furnished the material for this paper; to Major Kenneth Taylor, M.C., Commanding American Red Cross Military Hospital No. 2, for his helpful criticism; and to Sergeant John J. Owens, of Museum Unit No. 1, Army Medical Museum, whose drawings, which are reconstructions made from X-ray plates, have furnished most of the illustrations for this paper. The original drawings made by Sergeant Owens are on file at the Army Medical Museum, Washington, D. C., and it is through the courtesy of the Museum that reproductions of these drawings are used.

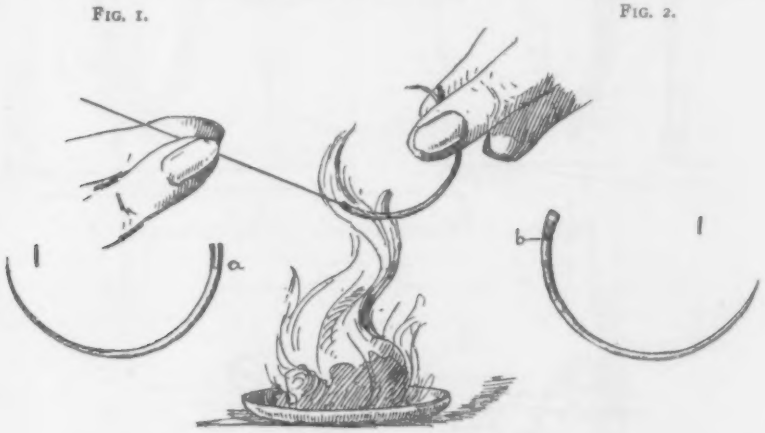
THE RAPID CLOSURE OF SURGICAL WOUNDS, SPECIALLY OF LAPAROTOMIES

By Angelo L. Soresi, M.D.
of New York, N. Y.

The rapid closure of surgical wounds, and specially of laparotomies, is performed with silver or bronze wire soldered on special needles, and kept in place by lead shots on both ends.

The instruments to be used and the *modus operandi* are the following: We use a special needle described in the *Revue de Chirurgie*, March–April, 1917, A. L. Soresi: *Aiguille modifié pour la suture avec fils metalliques.*

Fig. 1. Fig. 2.



2

Figs. 1 and 2.—Needles with a slot (*a*) and a tube (*b*) in place instead of the ordinary eye. *2* shows the easy manner of soldering wire to needle; any flame will do.

Fig. 3.—Special forceps showing (*a*) depression in which the shot is secured; a similar depression is found in the other jaw of the forceps. (*b*) cutting edges.

This needle, as shown in Fig. 1, has no eye, but instead ends with a small tube or a slit; in the tube or in the slit is put a little of any one of the quick solders on the market and the wire is inserted in it; the whole is then put on any flame, such as one obtained with a piece of cotton soaked with alcohol (Fig. 2), and heated; the wire becomes immediately soldered to the needle, and, if there is any excess of the solder sticking out, it is easily scraped away, so as to make the whole needle perfectly smooth.

FIG. 4.

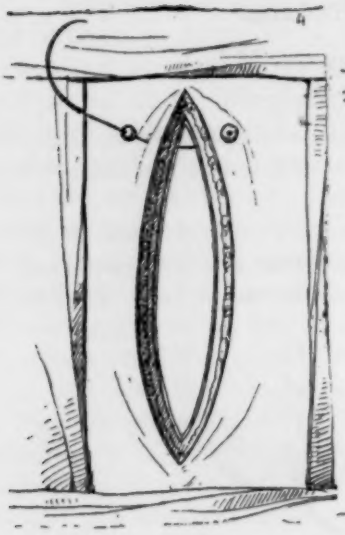
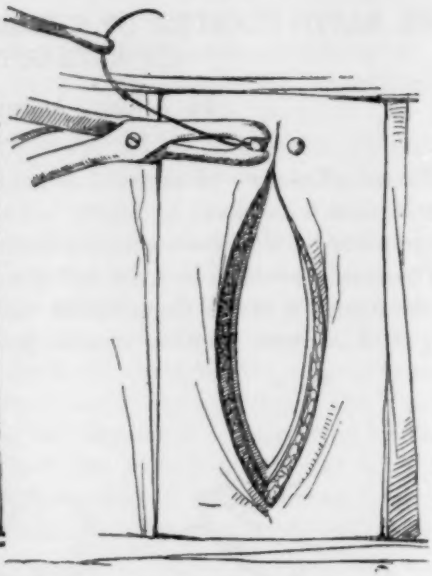


FIG. 5.



FIGS. 4 AND 5.—Showing how wires and shot are applied.

FIG. 6.

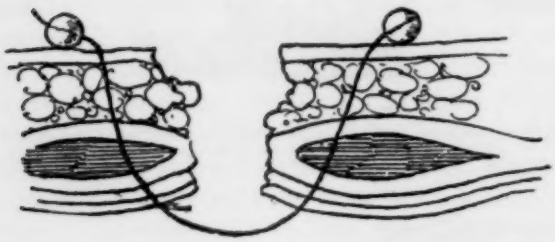
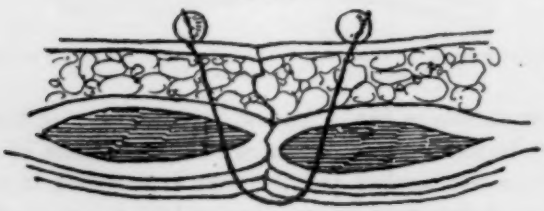


FIG. 7.



FIGS. 6 AND 7.—Schematic view of how wire penetrates (Fig. 6) and then (Fig. 7) approximates the tissues when wires are pulled taut and shots are squeezed.

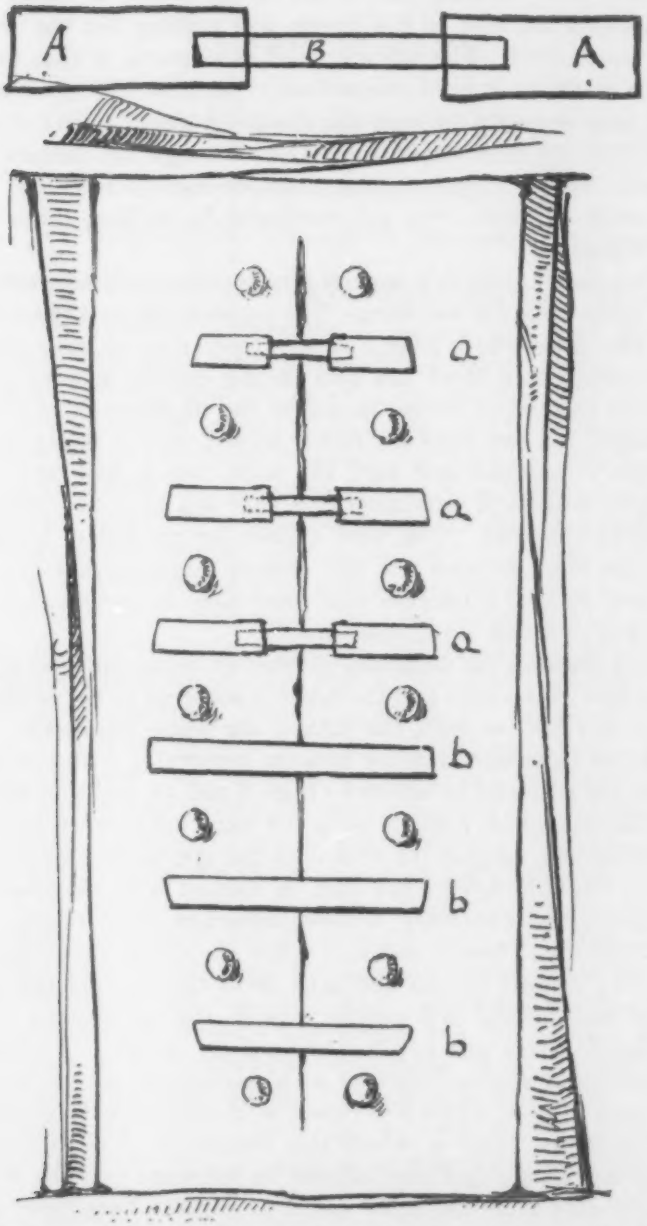


FIG. 8.—Showing how skin can be approximated with plain adhesive strips or with elastic strips; elastic strips are ideal and close the skin better than sutures and can be easily prepared by cutting two strips of adhesive *A A*; to these two strips of adhesive a piece of rubber band is attached by simply pressing the rubber band, *B*, against the rubber of the adhesive. The elastic strip so prepared is applied to the skin

We use a wire about twenty centimetres long, which serves for two stitches. The piece of wire that is left in the needle is easily removed by heating again the end of the needle and pulling out the wire when the solder has melted. The advantage of this needle is that the wire is not bent on itself, as it is in the ordinary needles; the bend making it difficult to pass the wire through the tissues, while the wire soldered on the needle, that we have described, passes through the tissues as easily as the needle itself. A sufficient number of such needles are prepared and kept ready for use; they are sterilized by boiling them with the other instruments.

The other instrument is a special forceps, that will squeeze the shot and at the same time cut the wire. The instrument, as shown in Fig. 3, ends with two jaws which have a round depression on their middle and behind the depression there are two strong cutting edges. The shot, with the wire through it, is put in one of the depressions of the jaws of the instrument, the two jaws are firmly closed, and in doing so the shot will be tightly squeezed and hold the wire, which will be cut by the cutting edges, when and only after, the shot has been squeezed and has firmly secured the wire. The wire cannot be cut before being snugly secured in the shot, because the two cutting edges cannot cut until the shot has been squeezed, because until then they do not come in contact.

The *modus operandi* is the following:

The nurse prepares the necessary number of wires, one end of which is already secured over a shot and the other is soldered to the needle. When the surgeon is ready to start the suture, the nurse hands him the wire, prepared as we have said, and the surgeon perforates with the needle the tissues that are going to be sutured (Figs. 4 and 5), pulls on the wire, so that the shot comes in contact with the skin, introduces another shot through the needle, catches the shot with the special forceps and, pulling on the wire, while he brings the shot in contact with the skin, so as to give the suture the necessary tension, squeezes the forceps. In rapid succession the nurse hands one wire after the other until the suture is finished. The closure of the abdomen with the method described has been found very useful and satisfactory in the continuous emergency work during the war and can be successfully applied in civil surgery alone in extremely urgent cases, or as a reinforcing suture of the abdomen and other organs, which are closed with the ordinary method. It is obvious that in the cases in which this method of closure is applied as reinforcing means, the last shot should be squeezed and the wire pulled taut and cut only after the other plans of sutures have been duly tied. The edges of the skin come in close contact spontaneously when this method is used, but if a most perfect approximation is desired, it can be obtained either with a few stitches or by applying strips of adhesive plaster as shown in Fig. 8, which give a scar almost invisible.

A. L. Soresi, M.D.

TRANSACTIONS
OF THE
NEW YORK SURGICAL SOCIETY

Stated Meeting held October 8, 1919

The President, Dr. William A. Downes, in the chair

GIANT-CELL SARCOMA OF THE TIBIA, EIGHT YEARS AFTER OPERATION

Dr. Frank Mathews presented a patient who was shown to the Society some years ago, and was now shown again because the condition had a definite bearing upon the paper of the evening.

Eight years ago this patient came to Doctor Mathews suffering from giant-cell sarcoma of the outer tuberosity of the tibia. During the operation of cutting down and scraping out the tumor he opened the knee-joint. It was impossible to close the cavity in the outer tuberosity and therefore the whole wound was packed with iodoform gauze. There was later an infection in the knee-joint; this was opened and resulted in a stiff knee. Doctor Mathews then lost track of the case, the patient coming under his observation again only a few weeks ago, at which time he had stereoscopic pictures taken of the leg in order to see what had taken place during the interval. The plate, which was shown to the Society, showed a definite cavity with no bone filling; there was a ring of the tuberosity still preserved; this was the result in a case eight years after removal of a giant-cell sarcoma, in which healing had been prompt.

Dr. Frederic Kammerer mentioned two cases of giant-cell tumor of the internal condyle of the femur that had come under his observation during the past six months. They were both operated on by thorough removal of the masses within the condyle and subsequent cauterization with concentrated carbolic acid and alcohol, as recommended by Bloodgood. In the first instance a curettement only was done six months ago, but this was followed three or four weeks later by another curettement and cauterization with concentrated carbolic acid. In the second the combined procedure was instituted at the first operation. The earlier case was practically healed. In the second case, where the tumor masses had invaded the soft parts through an opening in the condyle made at a previous operation, the bone cavity and the soft parts presented the appearance of healthy granulation tissue. Of course, it was too early to speak of any definite results in these two cases.

Dr. William B. Coley stated that this case brought up the important question of the proper treatment of tumors of the long bones, and called attention to his own conservative methods in dealing with long-bone

sarcomas. He said that he now had 16 cases well over three years in which he followed the conservative treatment. Of 40 tibia cases which he has had, only 3 were of the giant-cell variety. Stress was laid upon the great disparity of opinion among various pathologists regarding this diagnosis, stating that Platou, of Christiana, in the ANNALS OF SURGERY (March, 1918) had published an article in which he stated that it was practically impossible from microscopic examination alone to diagnose this condition.

Doctor Coley referred to a case of sarcoma involving 5 inches of the upper end of the tibia shown before the Society sometime last year, which was at first diagnosed as giant-cell sarcoma, but was found also to contain a number of spindle cells; in this case there was only a thin layer of cartilage shutting off the knee-joint. The knee-joint was curetted and patient placed on mixed toxins; there was a recurrence necessitating further curettement; there was still another, and quite rapid recurrence, and at this time radium treatment was given. A recent X-ray picture shows reformation of bone. In a second case of giant-cell sarcoma of the lower end of the tibia, curettement was followed three times by a recurrence, at which juncture Doctor Coley placed the patient upon the toxins and X-ray treatment; this patient is now well fourteen years later, with a good leg. Another patient with a sarcoma of the tibia, spindle-cell, periosteal, with metastases in the groin, is now well after two and a half years. Doctor Coley voiced the belief that simple periosteal growths could be let alone, but that the patient is given a better chance if to curettement and cauterization with concentrated carbolic acid and alcohol is added treatment with the toxins and radium.

FRACTURE OF THE SKULL WITH CEREBRAL HERNIA

DR. FREDERICK T. VAN BEUREN, JR., presented a boy aged twelve years, who came into Roosevelt Hospital last April, about six months ago, after having collided with an automobile truck. He was unconscious on admission and showed a lacerated wound in the left frontal region with a depressed fracture of the skull and a protrusion of cerebral tissue. As he was only semi-conscious at the time of operation local anæsthesia was employed without discomfort, the incision enlarged and several bone fragments removed, protruding brain excised and edges of wound débrided. There resulted a defect in the skull of about 9 cm. long and 5 cm. wide. The fracture ran down into the frontal sinus, and there was also a fracture of the nasal bones and a severe wound of the chin. The scalp wound was sutured and drained; it healed nicely except at the middle, where an infection occurred and where there followed a cerebral hernia pulsating and sloughing for about four weeks. The infection apparently came through the frontal sinus from an abscess which formed in the region of the nasal duct. Six weeks after the injury the patient was able to leave the hospital, the wound being practically healed. Since this time

he has made no complaint of headaches and has shown no other symptoms of trouble. His wound is firmly healed. There remains the defect in his skull, now measuring about 6 cm. by 3 cm.

OSTEOSARCOMA OF TIBIA

DR. WALTON MARTIN presented a boy of nineteen years, who was admitted to St. Luke's Hospital on June 9, 1919, with the history that in December, 1918, he had pain in the right knee, throbbing in character, intermittent and increased on walking. In April he noticed a swelling just below the knee and to the outer side. Pain gradually increased and he lost 38 pounds in weight. An X-ray picture showed a very large cavity in the head of the tibia. The growth, which proved to be a giant-cell sarcoma, was curetted out on July 16; the cavity has now decreased about one-half. After the operation the patient was transferred to the General Memorial Hospital where he received treatment with radium. Doctor Martin stated as his belief that the cavity in the tibia in this patient would present practically the same appearance in a year's time as the patient shown by Doctor Mathews.

SUPPURATIVE OSTEOMYELITIS WITH FAT IMPLANTATION

DR. WALTON MARTIN presented a man who had sustained a gunshot wound of the shoulder, the humerus being struck by a fragment of shrapnel. He originally presented a large cavity with sequestra. Ten sequestra were removed and the outer wall of the cavity taken away. The effort to crowd in the soft parts, however, was not satisfactory, as a considerable dead space was left on bringing them together. Therefore a piece of subcutaneous fat was removed from the abdominal wall and the plug of fat inserted into the bone cavity. The wound was closed by interrupted sutures. The lower part of this wound closed, but the upper part opened after the removal of the sutures on the eighth day, and the fat was then exposed. It gradually turned whitish and gave the appearance of a white slough with little globules of oil on the surface. Finally this slough came away and the wound healed.

Doctor Walton also presented a man who, in 1913, fell over a cliff, sustaining a compound fracture of the leg which became infected; from time to time sequestra were discharged. From 1913 to 1917 it was a continual round of healing and reopening of the wound, with removal of sequestra. He had five operations during this period. Doctor Martin first saw him in December, 1917, when an incision was made over the old cavity, a small sequestrum removed, and the walls of a tunnel extending through the tibia were chiselled away until sound bone was reached on all sides. The leg was then subjected to the Carrel-Dakin treatment for three weeks until smears showed only one staphylococcus to a field. A plug of fat taken from the abdominal wall was then placed in the tunnel of bone. The skin was so tense and bound down to the underlying tissue

from previous operations that it did not glide over the bone easily and was only brought together by interrupted sutures with difficulty, portions of the fat projecting between the interrupted sutures. The leg was then put up in plaster. There was no rise in temperature after the operation. After ten days the dressing was taken down; there were crusts over the fat projecting between the sutures where the blood had dried. The stitches were removed and another cast was applied. One week later the patient went south. On his return, after three weeks, the plaster was removed and the wound had healed soundly. At the present time the skin over the site of the wound was found to be freely movable and there was no pain or other discomfort. The leg has been healed for nearly two years.

Doctor Walton also presented a patient who was admitted, in 1916, to St. Luke's Hospital with osteomyelitis of the femur, with a secondary abscess in the popliteal space and an abscess to the outer side of the thigh. The wound was opened, the outer portion of a cavity in the femur dissected away, sequestra removed and the abscess in the popliteal space drained and filled with "bipp." The wound had healed by two folds of soft tissue turning in against the bone, leaving a deep gutter in the thigh. The knee-joint was stiff and bent at a right angle; it was now freely movable. The wound has been healed since November, 1918.

Doctor Walton also presented a woman of fifty-six years, who was admitted to St. Luke's Hospital fifty-four years ago at the age of fourteen months, with a suppurative condition of both arm and leg. Doctor Buck operated upon her at that time, making several incisions. The arm healed satisfactorily, but the leg continued to bother her from time to time. Twelve years ago she came to Doctor Martin with a chronic osteomyelitis of the tibia; he exposed the tibia, removed all the dead bone, but made no careful effort to approximate the soft parts. Seven years ago, five years after his first operation, she returned because of intolererable pain. He then performed an extensive operation, removing a considerable portion of the upper part of the tibia; that is, the outer wall of the bone cavity, and crowded in the soft parts. She developed a secondary abscess in the soft parts after the operation. This was opened and drained. The leg then healed and has remained soundly healed. She was free from a disability which she has had all her life.

Dr. Robert T. Morris asked Doctor Martin to express his opinion as to the best procedure in a case seen by him two days previously in consultation, in which there had been an operation on the frontal sinus, the anterior wall being removed, making a bad depression; there still remains an opening into the ethmoid region. Danger of infection through the ethmoids was feared by Doctor Morris in case a flap were lifted and fat inserted to fill the depression. He stated that in this case the question of a blood clot filling also came up for discussion, but paraffine was finally decided upon.

Doctor Morris said that he had experimented with fat grafts and believed that in nerve surgery it was an excellent method to lay a strip of fat along the line of suture, as by so doing it is possible to avoid the connective tissue invasion of the area of the suture; also with tendon splicing; a thin layer of fat interferes with the plastic exudate uniting tendons *en masse* again.

Doctor Morris then spoke of a case of osteomyelitis seen by him during the past year. The patient, a young girl of twenty, had an osteomyelitis of the left femur, the entire femur from the head to the condyles being nearly twice the diameter of an ordinary femur, and this had been discharging for some years. The question of amputation was considered, but Doctor Morris having seen Doctor Downes' cases at Camp Upton determined to make a long trough the entire length of the diaphysis of the femur in V form, and then with the Carrel-Dakin solution there would be a safety in leaving open such an enormous wound. A culture was made of the staphylococcus aureus found in the wound and from this culture a vaccine was made and this was used in the hope of overcoming any further infection. This patient was seen by Doctor Morris about three months after operation, at which time she was perfectly well, the wound having healed and the patient having gained rapidly in flesh and color. While it was too early to make any final report upon this sort of case, the gain to date was at least out of our former experience.

Dr. H. H. M. Lyle said that Doctor Martin has shown that dead spaces can be obliterated and healing hastened by employing fat grafts. Undoubtedly the use of this medium would be a valuable aid in the treatment of osteomyelitis, but the essential step in the whole treatment was the sterilization of the osteomyelitic cavity. Without this any method of plugging was doomed to failure.

The greatest thing learned in the war was that infected wounds could be sterilized, and it is upon this fact that the future treatment of osteomyelitis must advance. In the early years of the war the speaker had an extensive experience with osteomyelitis. This experience led to nothing but pessimism. In 1916 it was his privilege to be in charge of one of the first hospitals to adopt the Carrel-Dakin principles. The results obtained by these methods completely revolutionized his pessimism. The confidence coming from the knowledge that the vast majority of wounds could be sterilized by the proper application of the Carrel methods led to a prompt and energetic attack upon all cases of osteomyelitis. The results obtained were surprising. Doctor Gibson, of this Society; Doctor Sherman, of Pittsburgh; and others, saw many of the cases. In 1916 Doctor Lyle showed before the Surgical Section of the Academy Lumiere plates illustrating the course of healing of compound fractures with osteomyelitis. Formerly it used to take months and months to obtain a closure. With the advent of the Carrel methods it was obtained in

weeks. In some of the cases shown in 1916 the time required was only twenty-eight days from the time of the original infection.

It must also be remembered that it is not always necessary to obliterate the cavity if it is sterile and can be maintained so by closure. Doctor Lyle has in his possession X-ray plates showing this phenomenon. Examples of such closures are seen after bone cysts, sterilized Brodie's abscesses, and cavities left after curetting out giant-cell sarcomas, etc. Surgeons have been taught that they cannot close empyemas until the cavity was obliterated. This teaching is not strictly correct. If one can sterilize an empyema it is possible in a very large percentage of cases to close the chest wall before the cavity is obliterated.

Dr. Edwin Beer called attention to Doctor Martin's remark that before introducing a fat graft in these cases "it was important to get complete hæmostasis in the cavity;" this he had considered very difficult to obtain, and in doing a radical operation for osteomyelitis of the long bones it was almost impossible to obtain complete hæmostasis except by using very intense dry heat as suggested by Mosetig Moorhof. When overhanging soft parts are sutured or nailed (Neuber) into the bone gutter there is danger of infection and further trouble with incomplete hæmostasis. It is just possible that the fat in these grafts acts as a hæmostatic in cases described by Kolisher (pustatectomies), and this would explain some of Doctor Martin's successful results.

Dr. Seward Erdman stated that he recently had three cases on his service in a military hospital in which a different method of plugging the cavity was resorted to, and in two of these cases with apparent success. All these cases were of gunshot wounds, seton wounds with compound fracture, two in the humerus and one in the femur. Doctor Erdman said that the obliteration of the cavity by the removal of the outer wall was not always practical in such cases, and instead of using free transplants of fat without blood supply a pedicled flap of muscle tissue was drawn through the tunnel in the bone. He referred in this connection to the use of muscle as a hæmostatic in cranial surgery. He said that the piece of muscle must be larger than what would apparently fill the hole because of the tendency to shrink, and also that this flap should be sufficiently divided at its pedicle so that it would not retract. Also, that it usually was found necessary to suture the flap on its distal side to make sure of it maintaining the desired position. He also called attention to the fact that if the osteomyelitis is in the vicinity of joints and there are channels leading into the joint it is impossible to obliterate these by drainage or by chiselling away the bony framework. Two such cases under his care were treated by resection of the joint, and both healed very satisfactorily.

Dr. John Douglas said that Doctor Martin's success suggested that the method of free fat transplant would be an easy one to follow, but that he did not consider it to be easy at all. He referred to a case of his own on which he operated about three years ago in which there was a

large cavity with much thickened extremity of the bone, and in which he tried a transplant without success; the patient was thirty-four years of age and had a chronic osteomyelitis of the femur of fifteen years' duration. The lower end of the bone was enormously thickened and the cortex so thickened that an X-ray picture showed no cavity. It had been operated on several times, resulting in a large amount of scar tissue. At the time Doctor Douglas operated there was practically an acute condition, a recent abscess formation. This he curetted and sterilized to the best of his ability, and, believing that a free transplant would not grow, he made a flap transplant, leaving the pedicle attached, thus blocking, as he thought, the cavity completely; this was, however, unsuccessful, the patient developing a small sinus and returning nine months ago, at which time he was kept under Carrel-Dakin treatment for over a month when negative smears were repeatedly obtained from the wound. The cavity was then opened as far as possible, and it was found impossible to make a gutter because the cavity went to the true condyles. After thoroughly sterilizing the cavity a free flap was removed from the abdominal wall with which the cavity was packed; nevertheless, there still persists an unclosed cavity in the bone. Doctor Douglas then referred to a boy of nine years, suffering from an osteomyelitis of the upper end of the tibia. After six or seven operations in another hospital there still persisted a cavity of considerable size, and when the case came under Doctor Douglas' care he scooped out the cavity and found a very thin anterior wall. He did not believe the cavity would close and he therefore tried to break down the walls; having no curved chisel he used a curved periosteal elevator inside the cavity as a chisel and thus broke down through the anterolateral wall of bone without cutting the periosteum. He then turned in these flaps and used the Carrel-Dakin treatment, and he was glad to say that when this patient was last seen the wound was entirely healed.

Dr. Frederic Kammerer said he had attempted fat transplantation into bone cavities before the war on several occasions, but had had nothing but failures. One of his assistants at U. S. General Hospital No. 12, Major King, had, however, demonstrated to him, in a case of osteomyelitis of the tibia following a compound fracture (gunshot), the beautiful results obtained by fat transplantations after thorough disinfection of the bone cavity with Dakin's solution. Thorough disinfection was, of course, as Doctor Lyle had said, the principal factor in all these cases.

TRANSACTIONS

OF THE

PHILADELPHIA ACADEMY OF SURGERY

Stated Meeting held October 6, 1919

The President, Dr. George C. Ross, in the chair

ADVANCED CARCINOMA OF BREAST; NO RECURRENCE SEVEN YEARS AFTER OPERATION

Dr. Astley P. C. Ashhurst presented this patient as an encouragement toward doing thorough and wide-spread excisions for carcinoma. If in such a case as the present cure can be obtained by such means, how much more certainly should cure be anticipated if the same type of radical operation were uniformly adopted in early cases? He added that he had had occasion recently to operate on a case of wide-spread local recurrence in a case of carcinoma of the breast, one year after another surgeon had done a very incomplete operation, although the clinical diagnosis had been carcinoma from the first. This fact seemed to indicate that some surgeons were still so skeptical of cure ever being attained that they considered it not worth their while to expend the time and skill necessary for a complete extirpation. In the case of recurrence to which reference had just been made, the surgeon at the first operation not only did not excise the pectoral muscles, but he did not expose the axilla at all, nor did he even remove all the glandular tissue of the breast; yet the clinical diagnosis, confirmed by histological study, had been carcinoma from the first! He desired also to make a plea for habitual röntgenization of carcinoma patients after operation. In the case of the patient now presented, post-operative röntgen therapy was continued a long time.

The patient, a woman, forty-five years of age, was admitted to the Episcopal Hospital, August 3, 1912. There was a typical "rose ulcer" 7.5 by 5 cm. in diameter in the upper outer quadrant of the right breast. This ulcer had commenced six months previously, and for two years before that time the woman had known she had a tumor in her breast. When examined there was a hard tumor, the size of a goose egg, beneath the ulcer. This tumor was freely movable in all directions. There was a palpable and visible mass of lymphatics in the axilla, which also was movable. The ulcer was covered with an adherent gray slough. No lymph-nodes were palpable above the clavicle. There was tenderness over the liver, but no evidence of metastasis to this organ. The left breast was normal.

Operation, under ether anæsthesia, was done August 5, 1912, including

a clean dissection of the entire axilla, and removal of its contents, both pectoral muscles, and a wide area of superficial and deep fascia (beyond mid-line at sternum, and down almost to umbilicus) in one mass. It was possible to close all the wound except for a space 5 by 2.5 cm. below the clavicle. The time of the operation was three and one-half hours, and at its conclusion the patient received one litre of saline solution intravenously, being almost pulseless. (The excised specimen is illustrated in Plates V and VI of the speaker's text-book of surgery.)

By the second day after operation convalescence was established. Many of the sutures did not hold, some of the skin edges became necrotic, and six weeks after operation there was a clean granulating area the size of two palms. On September 30, this had contracted to an area the size of one palm, and this was covered with Thiersch grafts. Meanwhile röntgen ray treatment was pursued for a number of months.

The patient was kept under observation:

March, 1914: Her health was feeble, and she could not do much work. There was still an unhealed area, 2 cm. in diameter, which scabbed over from time to time. There was no swelling of hand or forearm, and only slight œdema of the upper arm; but the œdema increased if the arm was used much. She could get her hand to her head and back to her buttocks, but both motions were weak, and the latter painful. The extensive cicatrix sometimes caused a sticking pain in her lung, but there was no evidence of pulmonary metastasis.

August, 1915: Condition about the same.

September 24, 1919: Since the last note the patient's general condition has markedly improved. She does her own housework and looks after an epileptic son. The entire right anterior thorax is covered by skin tightly adherent to the ribs, but there is no evidence of recurrence locally or of metastasis. She has good use of her arm, raising her hand easily above her head, and putting it without difficulty to the small of her back. Except for slight weakness she thinks it as useful as her left arm. There is scarcely appreciable swelling of the hand and none of the forearm or arm. During the past year her appendix was removed at the Philadelphia General Hospital.

Dr. D. B. Pfeiffer called attention to the picture circulated by Doctor Ashhurst in which the outline of the tumor is very sharply defined from the surrounding fat and breast parenchyma. If this is a fair representation of the growth it would indicate a rather different type of tumor pathologically from the kind that are ordinarily met with. It is well known that tumors which well merit the name of carcinoma still show the most remarkable variations in character, and particularly in the most important characteristics of infiltration and spread. He had seen many cases in which there was a comparatively huge primary mass and but little spread and *per contra* others that produced large and early metastasis from an insignificant appearing primary growth. He recalled one

case with axillary metastasis so extensive as to defy complete removal, which required the most minute search through the breast before the primary growth could be found. It seemed to him—without wishing to detract from Doctor Ashhurst's excellent result—that the underlying pathology is more influential in the result than the completeness of the operation, for has it not been the lot of all surgeons to operate in earlier and seemingly more favorable cases only to find that they have not been able to get beyond the carcinomatous permeation? Of course, he believed, as does every one, that radical operation for carcinoma of the breast should be as extensive as possible, and this case teaches that we should not lightly consider any case as inoperable. It will be more unfortunate, however, if any should consider that by punctilious completeness of operation the handicap of late surgery could be overcome.

Dr. J. Stewart Rodman recalled two cases in which his father operated. One was a sloughing tumor and the patient when last heard from was well eleven years after operation. The other was one of a growth of each breast. This patient was well eight years after the first operation and seven years after the second. Undoubtedly cures do occur even in these advanced cases if the operation is carefully and thoroughly done.

Dr. John B. Roberts recalled one case of malignant tumor of the breast which he removed about 1899, in which the woman died about three years ago, making the period of cure somewhere about seventeen years. The tumor was not a sloughing growth, but was quite as big as a woman's fist. He did a thorough operation, removing the glands in the axilla and he thought above the clavicle. He did not remember whether the tumor was examined microscopically, but clinically it had every appearance of being a large malignant growth. The patient was about sixty to sixty-five years old.

Dr. J. Leon Herman said that a tabulated list of the reported instances of late recurrence of carcinoma after radical amputation of the breast is given by Doctors Deaver, McFarland and himself in their book on "Diseases of the Breast." A period of thirty years was the longest interval of time intervening between the time of operation and the reappearance of the cancer. There were, of course, all varieties of carcinoma included in this series.

The excellent result obtained by Doctor Ashhurst in this case illustrates the possibility of cure in mammary cancer by radical operation, even though the local appearance of the tumor indicates an advanced state of the disease.

It is of interest to recall that Doctor Halsted devised the radical operation and advised its routine employment with the knowledge that Volkmann and others had obtained far better results in advanced cases by removal of the pectoral muscles, together with the breast, than had been obtained in early cases by simple amputation of the diseased breast.

Doctor Ashhurst, closing, said that he had no doubt that the malig-

nancy of different specimens of cancer varies a great deal. He thought also that diminished lymphatic activity is to be taken into consideration. In patients nearly eighty years old it seems useless to do an extensive operation. If we merely amputate the breast there is not likely to be subsequent trouble. But it ought to be remembered how far the mammary gland extends beyond that which one sees. If one thinks the glandular tissue occupies a very small area, he shall be deceived: it extends nearly up to the clavicle, out into the axilla, and down toward the epigastrium. The entire mammary gland should be removed even in these incomplete operations on *very aged* patients.

HYSTERECTOMY FOR CHORIO-EPITHELIOMA; NO RECURRENCE SIX YEARS AFTER OPERATION

Doctor Ashhurst said that the two following cases were presented especially to emphasize the value of certain *measures of routine:*

1. Pathological examination of uterine scrapings in cases of abortion or miscarriage.

2. Removal of the cervix along with the uterus in abdominal hysterectomy. In 3 out of the last 17 hysterectomies he had done for fibroids there had been coincident carcinoma of the cervix.

Chorio-epithelioma, or deciduoma malignum (Sänger, 1888), is an exceedingly malignant tumor growing in the body of the uterus after pregnancy. The pregnancy frequently is terminated before term, and the most favorable cases are those in which the diagnosis is made by the pathologist from examination of retained tissues removed in such cases. Such examination never should be neglected. The tumor probably arises from the chorionic and not from the decidual tissues; it behaves like the most malignant types of sarcoma, giving early venous metastasis, especially to the lungs (78 per cent.) and vagina (54 per cent.), according to Dorland.

Agnes H., forty-two years of age, was admitted to the Episcopal Hospital August 9, 1913, for a recent abortion after a few weeks' pregnancy. The uterus was curetted, and the scrapings sent to the laboratory for examination, as a matter of routine. The pathological report (Dr. C. Y. White) showing a chorio-epithelioma, abdominal panhysterectomy was done August 19, 1913. The appendix vermiformis, and left tube and ovary, the latter being cystic, were removed with the uterus, but the right tube and ovary were left. The uterus was slightly enlarged, and when opened, a papillomatous tumor was found at the fundus. (The specimen is illustrated in Fig. 1031 of the speaker's text-book of surgery.)

The patient has been kept under observation since operation, and is still in excellent health. Examination in August, 1919, six years after operation, disclosed no evidence of recurrence or metastasis. She was forty-eight years of age, and for the last year had complained of symptoms of the menopause.

Panhysterectomy for Fibroids; Carcinoma of the Cervix Discovered in the Laboratory; No Recurrence Three Years After Operation

Cora L., thirty-six years of age, negress, was admitted to the Episcopal Hospital September 18, 1916, for profuse metrorrhagia. This was checked in the Receiving Ward by twisting on its pedicle a polyp which was protruding from the cervix. The patient's hæmoglobin was only 25 per cent. On September 22, because slight fever persisted, she was etherized, the soft and dilated cervix was caught in volsellum forceps, drawn down to the vulva, and the pedicle of the polyp, about 0.75 cm. in diameter and 6 cm. long, attached just above the cervix, was divided with scissors. The polyp itself was about 6 cm. in diameter. Very moderate bleeding occurred from the attachment of the polyp. The uterus was the seat of numerous fibroids.

October 6, 1916, two weeks after removal of the polyp, the patient's fever having subsided, and her hæmoglobin having risen to 35 per cent., the abdomen was opened, and complete panhysterectomy was done (*i.e.*, the uterus including the cervix and both tubes and ovaries were removed). The uterus was of medium size, containing several subperitoneal fibroids the size of hen's eggs or larger. Recovery was uneventful.

The laboratory report (Dr. C. Y. White) was that the cervix was the seat of *advanced epithelioma.*

The patient has been kept under observation and now, three years after operation, pelvic examination discloses no symptoms of recurrence, nor is there any evidence of metastasis.

GUNSHOT WOUNDS OF THE VASCULAR SYSTEM

Dr. Astley P. C. Ashhurst reported the following cases:

Case I.—*Dry lesion of axillary artery from bullet wound; death ten hours after ligation.*

Tony P., twenty-six years of age, was admitted to the Episcopal Hospital December 31, 1916, immediately after having been shot, while an innocent bystander in a street fight. The wound of entrance was at the posterior edge of the right deltoid, close to its humeral insertion, and there was no wound of exit. X-rays localized the bullet lodged against the second right rib. His radial pulse was equal on both sides, and apart from slight pain and swelling in the axilla, there were no serious symptoms. On the day after admission, however, weakness of the muscles supplied by the median nerve and paralysis of those supplied by the musculospiral nerve were noted. It was determined to explore the axilla to ascertain the nature of the nerve lesions.

Operation, January 5, 1917, by Doctor Ashhurst. Ether anæsthesia.

An incision was made from the middle of the clavicle downward and outward, in the space between the deltoid and pectoralis major, exposing the pectoralis minor. A finger was then passed

under the latter muscle, preparatory to its division, for exposure of the axillary plexus. As soon as the finger emerged at the lower border of the pectoralis minor a gush of arterial blood burst through at both borders of the muscle. It was evident that the bullet had injured the axillary artery and the primary bleeding had been checked by a clot, or that a slough in the wall of the artery had been separated only when the finger entered the axilla. The profuse hemorrhage was checked temporarily by the operator compressing the axillary artery with his left finger just below the clavicle, and with his right finger below the pectoralis minor. Removal of either finger released a perfect flood of arterial blood. Doctor Spruance, who was assisting in the operation, was then intrusted with digital control of the distal end of the artery, thus releasing the operator's right hand. Attempts were then made to clamp the artery above the lesion, but these proved ineffectual, owing to the depth of the wound and the inability to distinguish the structures. Doctor Spruance then compressed the subclavian against the first rib, controlling hemorrhage from the proximal end of the axillary, while the operator compressed the distal end and tried to clamp it; this also proved ineffectual at first, it being impossible to clamp the artery without pinching one or other of the nerve trunks; but finally the clamp was properly placed and the distal end ceased to bleed. Doctor Spruance then compressed the axillary just below the clavicle, while Doctor Ashhurst ligated (with a double strand of No. 2 chromic catgut) the third portion of the subclavian by the usual incision above the clavicle. This at once stopped the pulse at the wrist. After suturing the cervical incision, the axillary wound was again exposed and found to be dry. The axillary incision was then enlarged, dividing the tendons of the pectoralis major and minor. Removal of the hæmostats still in the axillary wound then was begun; removal of the last hæmostat was again followed by profuse hemorrhage which was not controlled by digital compression of the axillary below the bleeding point. It was now found that this profuse hemorrhage came as recurrent bleeding from the subscapular artery, there being a bullet hole in the axillary just opposite the origin of this artery (Fig. 1). Therefore the axillary artery was tied above and below the hole, and the subscapular artery was tied also. The axillary plexus of nerves was then examined: the median nerve had been bruised by hæmostats; the musculospiral nerve was contused, presumably by the bullet; the ulnar and musculocutaneous nerves were undamaged. The divided muscles were repaired and the wound closed. The patient was in a precarious condition as the result of hemorrhage, and died ten hours after operation, in spite of stimulation. It is possible that blood transfusion might have saved his life, but no donor was available.

CASE II.—*Recent bullet wound of right axillary artery, with diffuse traumatic aneurism; ligation of first portion of subclavian artery and of axillary artery above and below the wound. Recovery.*

Charles W., a private of the 104th Infantry, U. S. A., was hit by a

machine-gun bullet in the Argonne Forest November 9, 1918, at 4 A.M. He was brought to Evacuation Hospital No. 6 at Souilly, and operated on twenty hours later. Fluoroscopic examination by Captain Angell showed the bullet superficially placed in the right pectoral region. The wound of entrance was over the right shoulder posteriorly. There was an immense pulsating hæmatoma occupying the entire right pectoral region, which was discolored by the extravasated blood. The bullet was palpable just beneath the skin, and the hæmatoma appeared on the point of rupture. There was no pulse at the right wrist.

Under ether anæsthesia, immediate operation was undertaken, with the skillful assistance of Captain Morse and Lieut. H. S. Kerchner. It was determined to do preliminary ligation of the first portion of the subclavian, as the immense size of the hæmatoma rendered the third portion inaccessible through healthy tissues, and then to expose the axillary artery where wounded. Accordingly an incision was made along the inner end of the right clavicle and downward for 7 cm. over the sternum, and the inner end of the clavicle (2.5 cm.) was resected. The pleura was accidentally punctured. The first portion of the subclavian artery was then exposed, and the pneumogastric nerve and its recurrent laryngeal branch were identified. Owing to the large size of the hæmatoma, these structures lay at an abnormal depth. A ligature of No. 2 chromic catgut was passed around the artery distal to the nerve (Fig. 2). On tying this ligature pulsation in the hæmatoma stopped at once, and the mass decreased in size. The operative incision was closed in layers, without drainage. A second incision was now made in the line of the axillary artery from the clavicle to the anterior axillary fold, dividing the pectoralis major and minor muscles. The bullet was removed from beneath the skin, and the clots evacuated. Free arterial bleeding then occurred from the proximal end of the axillary artery just distal to the clavicle, evidently recurrent through the thyroid axis and other branches of the subclavian distal to the ligature. This bleeding was checked by the finger and then by hæmostatic forceps, when it was seen that the bullet had clearly and completely divided the first portion of the axillary artery, without injuring the vein (Fig. 3). Both ends of the artery were ligated with No. 2 chromic gut and the wound was left wide open, and drained by rubber tissue. It was directed that the patient be not evacuated.

The next day the patient's hand was warm, and the circulation appeared to be reëstablished. He could flex his fingers, and the axillary plexus of nerves apparently had escaped injury. He has been very hoarse since the operation, perhaps from operative injury of the recurrent laryngeal nerve. The wounds were dressed: the sternal wound was healthy, but the pectoral wound smelled of gas gangrene, and a smear showed the presence of the B. aërogenes capsulatus. It is to be remembered that the tissues in the axilla were widely lacerated by the escaping blood and had been under increasing pressure from the hæmatoma for twenty hours before opera-

tion, and after operation were still deprived of their normal blood supply. At the time of operation the patient's condition did not warrant an excision of all the muscles which were infiltrated with blood. French anti-gas gangrene serum was administered, and the wound was treated with Dakin's solution according to Carrel's technic.

On the third day the patient was still very hoarse, but the pectoral wound looked better, though the muscles were still very spongy. It was noted that he was unable to extend his fingers or wrist, but it was not determined whether this was due to weakness or to a nerve lesion.

Five days after operation the patient appeared convalescent; though he was still very hoarse, and had a little cough; the wound was doing very well.

Six days after operation he was evacuated in good condition: the sternal wound had remained clean, and the pectoral wound was doing well.

Inquiries from the War Department as to the patient's subsequent history have been unanswered.

CASE III.—*Direct arterio-venous fistula of the axillary vessels following wound by shell fragment. Excision of vein, suture of artery. Recovery.*

George W., private, 39th Infantry, U. S. A., sustained a penetrating wound by a shell fragment August 1, 1918, in France. The wound of entrance was in the left deltoid region. He was taken to a hospital and put to bed. No operation was done. He did well, presenting no noteworthy symptoms. After a few days he got out of bed, and soon began to work about the ward. One night (about 2 A.M.), eight or ten days after injury, he was awakened by pain in the left subclavicular region and down the left chest. Examination by the ward surgeon revealed a blowing murmur in the left subclavicular region. Previous examinations, he said, had shown a heart murmur, but nothing abnormal in the axillary region.

This patient first came under Doctor Ashhurst's notice seven months after his injury, in the Walter Reed General Hospital, Washington, D. C., where he was in the service of Major E. M. Jones, who asked Doctor Ashhurst to operate. The disability consisted in inability to raise the arm above the head, this motion being only two-thirds of normal. There was a buzzing and whirring on palpation below the left clavicle, but the radial pulse on the two limbs was equal and synchronous, and the blood-pressure was normal on both sides. Skiagraphic examination showed a shell fragment 3 cm. anterior to the vertebral end of the fourth left rib. This fragment, of medium size, was producing no symptoms and its removal was not indicated.

On March 27, 1919, with the skillful assistance of Major Jones and Lieut. J. C. Lawlor, Colonel Ashhurst operated under ether anæsthesia; as the site of the lesion evidently was high in the axilla, it was determined first to control the circulation by clamping the third portion of the subclavian artery, which was done through the

classical incision. Next an incision was made, convex toward the greater tuberosity of the humerus, from the middle of the clavicle to the anterior axillary fold near the chest wall. After ligating the cephalic vein, the tendon of the pectoralis major was divided, and the axillary artery was clamped just proximal to the origin of the subscapular artery. The tendon of the pectoralis minor was then cut, and the clavicular origin of the pectoralis major divided for about 3 cm. The lesion could then be identified, after dissection of scar tissue, as a direct arterio-venous fistula of the axillary vessels, involving the first portion of the axillary artery. The outside diameter of the fistula was about 1 cm. (Fig. 4). Artery clamps were now applied just proximal and just distal to the lesion, and the clamps which for about one hour had been on the subclavian and on the third portion of the axillary were removed. The axillary vein was carefully cleared, ligated above and below the lesion, cut across between the respective ligatures and the lesion, and dissected free as a pouch attached to the artery (Fig. 4). A grooved director passed across the venous pouch through the fistula into the lumen of the artery, demonstrated completely the nature of the lesion. Three interrupted sutures of fine linen were now passed through the arterial wall at the site of the fistulous opening, and were tied after cutting away the venous pouch from the artery. Then a continuous through-and-through linen suture was applied to the artery, and the arterial clamps were removed. There was absolutely no leakage from the suture line as the artery filled out and pulsated, but a branch of the acromio-thoracic artery below the lesion spurted actively and was tied. The pectoralis major (not the minor) and the skin were closed separately with chromic gut, a small tube being left at the lower angle of the large wound. The neck wound was closed without drainage. The duration of the operation was three hours.

Recovery was uneventful, no abnormal symptoms of any kind being observed, and function of the arm being gradually restored. The patient returned to his home and has recently been carefully examined by Dr. Lucian H. Landry of New Orleans, one of Doctor Matas's associates, who courteously wrote to me September 15, 1919, that after a careful examination he considered the result a complete cure.

CASE IV.—*Circumscribed traumatic aneurism of sural artery following wound by shell fragment; obliterative endo-aneurismorrhaphy; recovery.*

Richard B., first lieutenant, twenty-four years of age, U. S. A., suffered a perforating wound of the right popliteal space by a minute shell fragment September 26, 1918. The punctured wounds of entry and exit healed without any operative treatment, but after some weeks, while walking, he felt a sudden sharp pain in the bend of the knee and a pulsating tumor appeared. He came under Doctor Ashhurst's notice, more than five months later, in March, 1919, at the Walter Reed General Hospital. Low in the right popliteal

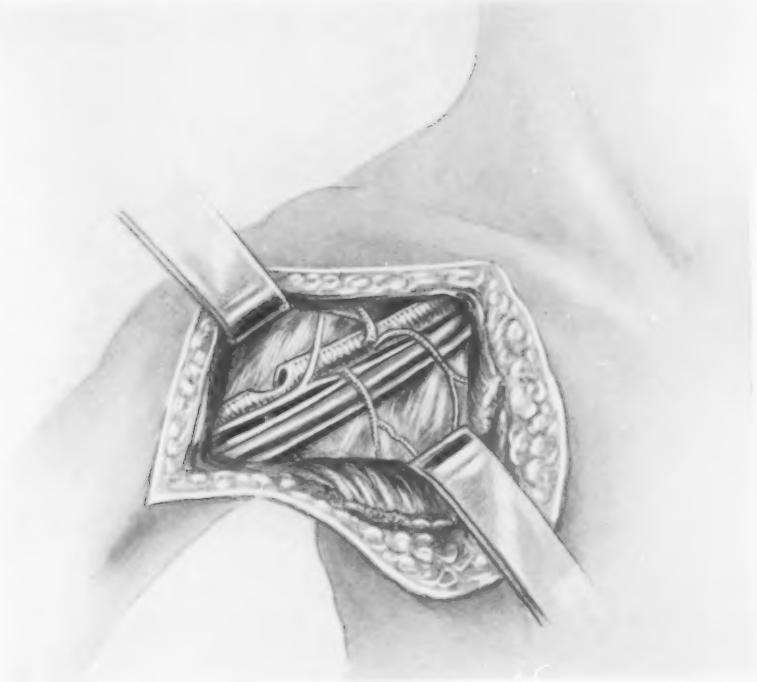


FIG. 1.

FIG. 2.

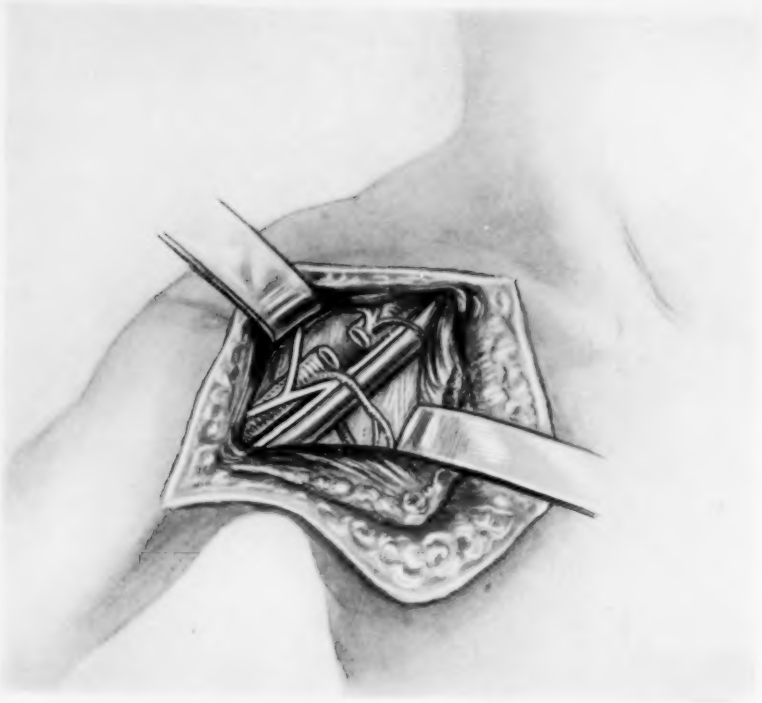


FIG. 3.

FIG. 4.

space was a tense, hard, not tender swelling, 7 by 5 cm., its long axis corresponding to that of the limb. This swelling exhibited distinct expansile pulsation and bruit. There was no appreciable difference in the pulse below the knee in either leg.

Operation was undertaken March 6, 1919. Under Esmarch anæsthesia a longitudinal incision, 16 cm. in length, was made over the popliteal space, and the deep fascia and heads of the gastrocnemius muscle, as well as the internal popliteal (posterior tibial) nerve, were dissected off the sac, all of these structures being densely adherent. The sac was opened on its median side, and some well organized clots were evacuated. The sac was found to be of the size of a large hen's egg: its walls were formed of organized granulation tissue, except for an area about 3 by 2 cm. on the median and anterior surfaces, which was white and glistening, representing the original intima of the wounded artery, now spread out to form part of the sac wall. This patch of typical intima contained two minute orifices—one proximal, the other distal—about 2.75 cm. apart, evidently representing the afferent and efferent channels for the blood. The proximal opening bled a little. There were no other openings in the sac. Most of the posterior wall of the sac was dissected free and excised; the arterial orifices were closed by linen sutures; and the remainder of the sac, which was too adherent to be excised easily, was obliterated by No. 000 chromic gut sutures. The fascia and skin were closed separately. The time of the operation was about one hour.

Recovery was uneventful, all the symptoms being relieved.

PERFORATING GUNSHOT WOUND OF THE ABDOMEN WITH INVOLVEMENT OF LIVER, KIDNEY AND SECONDARY INFECTION OF PLEURA

Dr. John H. Jopson reported the following case: B. R., private, Company L, 61st Infantry, was admitted to Evacuation Hospital No. 1, A. E. F., on September 6, 1918, at 3.30 P.M., with the diagnosis of gunshot wound, perforating, of the right abdomen. He had been wounded at 5 A.M. of the same day. On admission he was suffering from the effects of hemorrhage and was in poor condition. He presented on examination a large wound, probably of entrance, below the lower border of the thorax, about the nipple line on the right side, and a wound somewhat larger at a corresponding point posteriorly. Preparations were made for immediate operation. To render this possible blood transfusion was necessary, and was started at the commencement of the operation. The anterior wound first received attention, and was débrided, and the abdomen opened by a free incision. There was an extensive laceration of the right lobe of the liver, which was bleeding freely, and was the source of most of the abdominal hemorrhage. This was packed. The tract of the éclat was followed backward through the posterior peritoneum and the retroperitoneal space was opened widely. The right kidney was pal-

pated, and found to be badly lacerated. It was delivered through the opening into the peritoneal cavity, the pedicle ligated, and thus removed transperitoneally. The patient was then turned on his face, after partially closing the abdominal wound and packing the remainder down to and through the posterior peritoneum. The wound in the back, from which much of the blood which we had been pouring into the vein was meanwhile pouring out, was then widely débrided, exposing in the process a comminuted fracture of the eleventh rib, fragments of which were removed, and a large wound thus established traversing the entire upper abdomen. The posterior wound was also packed, the two packs, anterior and posterior, meeting, and the operation concluded. Contrary to expectations, the following day found the patient in very fair condition, and with undiminished pluck and cheerfulness. There were no evidences of peritoneal infection, and he was suffering from the effects of hemorrhage only. In spite of this, however, his after-course was most stormy, and not lacking in complications. It was not deemed wise to remove the packs after twenty-four hours, and begin Carreling as was our custom in ordinary gunshot wounds not permitting of primary suture. We have not been in the habit of using this method of treatment in wounds with a wide communication with the abdominal cavity, and it was decided to leave the packs in place for a longer time. Some of the gauze was removed on the third and the remainder on the fifth day, the latter date gas being administered. The anterior wound was found infected, and all sutures were removed. The general condition was good; there was a superficial infection of the posterior wound, as well as the anterior, streptococcal in nature, and two days later the wounds were Carreled. Under this treatment they cleaned up rapidly, and the wound was steadily reduced in size by granulation. The temperature, however, gradually rose after a few days, and on the 5th of October he had a chill and a fever of 102°. He was still decidedly anæmic, and an annoying symptom appeared in the form of vomiting at intervals of once or twice a day, of a considerable amount of bile-stained fluid. At the time there appeared evidences of effusion in the lower part of the right chest, which aroused suspicion of an ascending subphrenic infection, for which there was ample explanation. The first aspiration of the pleural cavity was negative, but the second, on October 9, was positive, and 600 c.c. of light brown but sterile fluid were withdrawn. On the same day an exploration of the subphrenic space was made. A vertical incision across the twelfth rib exposed the same, and it was resected for three inches. The edge of the diaphragm was divided, underlying adhesions separated, and the subphrenic space exposed without opening the pleura. The wound of the liver, still gaping and covered with lymph and granulations, was uncovered, and the right upper abdomen, above and below the liver and over as far as the stomach, was examined, but with negative results. After this operation he was somewhat depressed, and my assistants, who

were all deeply interested in the soldier, and pessimistic and hopeful by turns, were correspondingly lugubrious. Carrel again after two days. By the fifteenth the pleural fluid had reaccumulated and its presence was confirmed by examination of Lt. Col. George W. Norris. Aspiration at this time yielded a fluid, which while still amber colored, showed the presence of streptococci, and on the following day the patient was again sent to the operating pavilion, and the chest drained by resection of the eighth rib in the mid-axillary line, and the insertion of drainage tubes. Following this procedure there was a slow but steady improvement marked by subsidence of temperature, cessation after a time of the vomiting, which we had been inclined at one time to view as a possible result of duodenal obstruction by some collection, and a slow improvement in the general condition. About this time, however, the patient developed a most harassing and troublesome cough which resisted all medication, but which, like the vomiting, finally subsided. A small fecal fistula had appeared, possibly as a result of the second operation, but by the first week in November this, too, had closed. Slight elevation of the temperature persisted from time to time until December. Finally, on January 13, as the thoracic sinus still persisted, and improvement seemed slow in the local findings, as far as the chest was concerned, although the abdominal wounds were by this time long cicatrized, the seventh rib was resected under gas-ether anæsthesia, and eight days later he was evacuated.

After leaving the evacuation hospital, he passed through two base hospitals, was sent back to the United States in March, and after another transfer was sent to the Walter Reed Hospital, from which he was discharged on October 4, 1919. The drainage tube was removed and replaced several times during this period of his hospitalization, but when examined on October 6 the wound was solidly healed, and had been so since May.

At present there is slight discomfort in the right side on deep breathing. Hæmoptysis, slight in amount, has been noted after unusual exertion. There is some limitation of expansion on the right side, no râles, a slight lateral curvature, a much depressed scar over the site of resection of the seventh rib, the other scars, anterior and posterior, solid and showing no signs of hernia. The man weighs nine pounds more than on entering the service, and looks to be in splendid health.

That this man survived was mainly due to the fact that in him we were dealing with a type of patient that unfortunately, while the rule in the army, is not the consistent type in civil life, as one quickly finds when one resumes wonted work. The healthy young male human animal, with unimpaired organs, and a marvellous reacting power, is possibly the nearest approach to the laboratory animal in responding to all of the measures for the treatment, operative or otherwise, for traumatic conditions and their concomitant complications of shock, hemorrhage and infection. We are enabled to follow the problem to its solution in a far

larger percentage of cases than we can in an equal number of adults representing a cross-section of the community in general. In their ability to react completely and rapidly from an apparently hopeless state due to pure shock or shock and hemorrhage combined, they resemble a healthy child, while able, of course, to take an amount of physical punishment far in excess of the latter. With them it is much less frequently a case of the operation being a success but the patient dying, their undamaged viscera and whatever portion of the nervous mechanism or undiscovered physiologic reservoir which is called into action in the production and the reaction from shock *per se*, standing them in good stead at every step in the pathway from the time the injury is inflicted until convalescence is complete.

STAB WOUND OF DIAPHRAGM AND STOMACH

Dr. James H. Baldwin reported this case to emphasize a fact well known to all surgeons, but not so well known to those who do not do surgery—that the earlier an abdominal perforation is treated, the more likelihood that the patient will recover and that most patients operated on in the first few hours after a perforation do recover.

E. B., aged twenty years, was admitted to the Methodist Hospital at midnight, August 26, 1919, with a history of having received a self-inflicted stab wound of the left chest at the eighth costal cartilage region, about one-half hour previously. The patient, on admission, was intoxicated, vomited freely, with a report of "no blood in the vomitus." The temperature was 98°; pulse, 80; respiration, 20. The wound, from which very little blood came and which did not look dangerous, was dressed by the interne, Doctor Harding, and orders given to watch the patient, making frequent chart records. In a short time the pulse rate began to increase, upper abdominal rigidity with marked pain and tenderness developed. I was sent for and operated at once, four or five hours after the receipt of the wound. A left rectus incision was made from the costal margin downward. On opening the peritoneal cavity, there was a gush of air and blood and the whole abdominal cavity seemed filled with bright red blood. This obscured the field, but with the use of large wet packs, the field could be cleared sufficiently to see a wound about one inch long in the greater curvature of the stomach, a few inches from the cardiac end. This was easily closed and the hemorrhage controlled. No other wound was found in the stomach or intestines. There was an opening through the diaphragm about one inch in length. By retracting the abdominal wall, this could be sutured and was closed with catgut. The abdominal wall incision was then closed as usual with two cigarette drains at the upper angle. The chest wound was then examined and it was found that the knife had severed the cartilage of the eighth rib.

The post-operative recovery was uneventful. Hot water was given in small amounts about twelve hours after the operation. The tempera-

ture and pulse were slightly elevated for a day or two, but soon dropped to normal, and the patient was discharged on the sixteenth day fully recovered.

Dr. John H. Jopson said that transthoracic penetration of the abdomen is a frequent injury in war surgery. Most of the cases are due to high explosives. He recalled four cases on which he operated, in which the missile or weapon went through the pleura and diaphragm, and in which he operated through the same route. In three of the cases the wounds were produced by shell fragments; in the fourth the injury was a bayonet wound, and in this case there were some points of similarity with the one reported by Doctor Baldwin. The soldier was going up to the trenches at night with a small group of men in a new area. They were mistaken in the darkness for Germans by another party of Americans, and in the mêlée this soldier received two penetrating bayonet wounds in the right chest, one in the second interspace, nipple line, and the other in the eleventh interspace, behind the post-axillary line. He was brought into the hospital in a few hours later in good condition. The upper wound in the front of the chest was first sutured. The lower and posterior wound was then explored. The chest was widely opened in the eleventh interspace, débriding the wound in this procedure, and a wound of the diaphragm discovered one and a half inches from its costal attachment. This was easily reached and sutured. The lung was collapsed, but not bleeding. Air-tight closure of wound was made. The patient was then turned on his back, and the abdomen opened through the right rectus muscle. Little blood was found in the abdomen; there was no injury of the hollow viscera, but another wound of the diaphragm was discovered near the mid-line and behind the dome of the liver, and so far back as to be inaccessible to suture through the abdominal wound. We therefore closed this wound, and reopened the wound in the thorax, resecting the eleventh rib to give a better exposure. The bayonet had gone through the diaphragm, probably wounding the liver slightly on the retroperitoneal surface, and re-entered the pleural cavity near the mid-line, passing along the arc of the diaphragmatic curve. By pushing down the diaphragm and liver, after excision of the rib, we were enabled, with some difficulty, to suture the oval opening in the diaphragm and without the aid of negative pressure. The patient breathed well in the prone position, except when the downward pressure was made as described. Air-tight closure of the pleura for a second time. The man developed a streptococcic infection of the pleura, which demanded reopening of the chest on the sixth day, and the insertion of Carrel tubes. Chest irrigation was not well borne, and simple drainage was substituted for it. The patient reacted well to this plan of treatment, and was evacuated in good condition five weeks after admission, with a sinus remaining. Such experiences were rare, and we seldom saw bayonet wounds of any kind, and these usually accidental. The advantages of the transthoracic route for certain lesions in the subphrenic space is well recognized.

Two cases of shrapnel wounds of the liver with lodgment of the foreign body in that organ were treated in this way. In another case the wound in the liver was exposed transpleurally and packed; no foreign body was found, although the abdomen was opened again from in front, and explored. All of these cases recovered.

DR. MORRIS BOOTH MILLER said that in the spring of 1917 he had a case similar to Doctor Baldwin's, except that the stab wound was farther to the left and hence an interspace higher up. There was a transpleural wound of the abdomen. He opened the pleura and sutured the diaphragm from above. The wound was made by a stiletto in the hand of an Italian who had evidently meant to make a thorough job by turning his hand as he struck. This gave a substantial slash of the diaphragm. After suturing the diaphragm he opened the abdomen but found no visceral perforation; one or two little cuts had been made in the omentum. He was not so fortunate as Doctor Baldwin, because his man developed a virulent infection of the colon bacillus type and in spite of the fact that early drainage of the pleura was instituted the patient succumbed to the infection.

CORRESPONDENCE

THE PREPARATION OF THE SKIN FOR OPERATION WITH SOLUTION OF RUBBER AND ETHER INSTEAD OF TINCTURE OF IODINE

EDITOR, ANNALS OF SURGERY:

While all the merit for the simplification of the technic of preparing the skin previous to surgical operation is due to the venerable surgeon of Fiume, Doctor Grossich, now engaged in political strife for a patriotic ideal, the use of rubber and ether solution represents a progress over the Grossich method of using tincture of iodine. We have employed the plain rubber cement used in repairing tires and sold at any store selling motor and bicycle supplies, and the solution is prepared in the following manner:

A glass container, with ground glass cover, is sterilized and filled with one part of the rubber cement and about five parts of ether. The container is shaken, so as to dissolve the rubber cement in the ether, and is allowed to stand for a few days. The solution is applied to the dried skin by painting it over the operative field, as is done with tincture of iodine. The solution dries almost immediately, so a second and, if desired, a third coat can be applied. The surgeon can then proceed to operate. The ether rubber solution leaves on the skin a film of rubber that will adhere to the skin and prevent any infection from the skin itself.

The drawbacks of tincture of iodine are so well known that we shall not even mention them; we shall only mention some of the advantages, especially in cases of laparotomy, of the ether rubber solution. It does not irritate even the most delicate skin. The tincture of iodine applied to the skin has been the cause of many post-operative adhesions, because, notwithstanding the fact that the skin was covered with sterile gauze, the direct contact with the iodine, or even its vapors, helped by the friction of the abdominal organs against the gauze, caused irritation of the peritoneal surfaces, resulting in the formation of adhesions. This drawback is completely eliminated if rubber ether solution is used. The use of the ether rubber solution has also allowed us to reduce the amount of packing around the laparotomy incision; in fact, when performing aseptic or quasi-aseptic operations, such as gastro-enterostomies or appendectomies in non-acute cases, we do not cover the abdomen as is usually done, but use sheets with large rectangular holes and we lay the organs that are extracted from the abdomen right on the abdomen itself without any interposition of gauze, because the friction of the gauze, whether dry or wet, is a great help to the formation of adhesions, while

the rubber film deposited on the skin is practically non-irritating to the peritoneal organs, and we limit, when necessary, the packing to the indispensable to prevent leakage of infected contents in the abdominal cavity.

If adhesive plaster is used to hold the dressing, the plaster adheres better to the skin prepared with the ether rubber cement than to the bare skin, as described in a short note in the *Journal of the A. M. A.*[1] The ether rubber solution is absolutely sterile as shown by the report appended,[2] and we advise allowing the solution to stand for a few days, so as to be sure that the solution becomes sterile through the action of the ether.

We are now trying to color the solution so that its application to the operative field can be made more easily uniform and even; when we have found which appears to be the most suitable color, we shall make another short report of the results obtained.

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SPLENECTOMY UNDER LOCAL ANÆSTHESIA

EDITOR ANNALS OF SURGERY:

I desire to place on record the following case:

The patient was a woman, aged fifty years in 1912, when her spleen was removed under local anæsthesia. Resident of St. Louis County, Mo., housewife, mother of ten children, of whom six were alive and well. Sixteen years previous had had chills and fever of two months' duration. She has had severe attacks of pain and cramping in the abdomen, sometimes in one quadrant and sometimes in another. The menses were regular until 1911 in January. Since then they were irregular, at intervals of five or six months, with flooding; nervousness, hot flushes, etc., were absent. She came seeking relief from bladder trouble and pain in the back. For six years she had noticed an irregular tumefaction in the lower abdomen. She relates that at first it was movable. Three months before the original examination it became suddenly larger, and since then was immovable, and the pain in the bladder and the lower part of the back increased. She also had pain in the higher part of

[1] A. L. Soresi: "How to make even poor adhesive plaster adhere." Journal A. M. A., September 6, 1919.

[2] The rubber cement in ether given me to examine bacteriologically was cultured in the following media: Plain broth, glucose broth, plain agar, glucose agar, and blood agar. Gelatin plates were also made. All media were adjusted to hydrogen-ion concentration of $pH = 7.1$.

All sets of media were cultured both aërobically and anaërobically.

There was no growth obtained on any media after twelve days, when the cultures were discarded as sterile.

October 14, 1919. W. MOITRIER.

FIG. 1.—Convex surface of spleen.

FIG. 2.—Cut surface of spleen. Note structure.

the back. The patient complained of much gas in the bowels, especially at night, and constipation was an increasingly troublesome factor.

Examination.—All four quadrants of the abdomen were tender. The tumor filled the pelvis and presented above the pubis. It was irregular in its outlines and very hard, and should have suggested spleen on examination except that the characteristic notches were presented upward, giving a very different impression than that produced when they present normally. On bimanual examination the mass was found wedged in the pelvis and apparently continuous with the uterus, or at least not separable. The mass was tender and immobile and of a hard consistency.

Operation, under ether, disclosed that the tumor was an enlarged spleen wedged in the pelvis. It was freed and returned to its normal position after the surface had been rubbed with gauze. It was hoped that antimalarial treatment and the relief of passive congestion which the torsion of the pedicle had caused might result in the resolution of the tumor. A further inspection of the abdomen showed a definitely inflamed appendix and a gall-bladder full of stones. The appendix and the stones were removed and the gall-bladder drained. The patient took the ether poorly and the recovery period was stormy and characterized by cyanosis and irregular cardiac action. The period of nausea was prolonged. The spleen was retained by abdominal binders and pads and the head of the bed was kept low. The wounds progressed favorably. During her recovery period a very careful examination of the blood gave no information to guide us. Nevertheless, an intensive antimalarial course was given without result. She returned by agreement four months later. The spleen had slipped down again, but was still mobile; the bladder symptoms were as bad as ever, although practice of the knee-chest position tended to relieve.

Second Operation.—Novocaine and adrenalin solution were used in the skin and the line of incision. Quinine and urea hydrochloride solution was injected deeply at same distance on each side. A high rectus incision was made and the spleen pedicle lifted into view. A multiple ligation was done with careful avoidance of the tail of the spleen, Pagenstecher linen being used. Then the pedicle was divided and the spleen afterward lifted from the abdomen. The length of the pedicle greatly facilitated the procedure. The recovery period was remarkably smooth in contrast to that after the first operation. The wound healed well, the cardinal symptoms were relieved. Several blood studies did not reveal any marked disturbance. The patient remains well.

Pathology.—The spleen weighed three and one-half pounds. It was fairly smooth on its surface except for some whitish deposits thickening the capsule. The cut surface showed an appearance of structure, illustrated by the photograph, as of a cortex and medulla. The sections were prepared by the kindness of Doctor Hertzler and showed great increase of cells of an endothelial type, *i.e.*, large

cells with a clear glassy cystoplasm and small, well stained nuclei. This seems to conform to the Gaucher type, although the history is not classical.

Comment.—In cases of floating spleen the long pedicle renders splenectomy under local anæsthesia feasible.

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DISLOCATION OF THE FIVE METATARSAL BONES DOWNWARD AND OUTWARD FROM THE TARSUS WITHOUT FRACTURE

EDITOR, ANNALS OF SURGERY:

The excuse for reporting this case lies mainly in its rarity. In looking up the literature we find that there are only ten cases reported (Stimson, on Fractures and Dislocations). Furthermore, neither of us in quite an extensive emergency practice, has ever seen its duplicate.

The subject of this report, Mr. R., married, aged fifty-five, was injured while working in a soap factory. Claims to have never been injured before. The present accident occurred when a 1200-pound soap vat fell on him, causing a fracture of both the tibia and fibula above the ankle-joint in the right leg, and a dislocation of the metatarsal bones in the left foot. The causative factor in this case undoubtedly must have been direct violence, first dislocating the metatarsal bones posteriorly and then outwardly. If one will look at the anatomy of the second metatarsal bone he will see that there is an interlocking between the second metatarsal and the first and third cuneiform bones so that a dislocation of this type without fracture must involve either an anterior or a posterior dislocation of the second metatarsal bone.

Reduction of the dislocation was easily accomplished under an anæsthetic. Recovery was complete and the man returned to work in six months, the lengthened disability being due to the fracture in the other leg.

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FIG. 1.—Dislocation downward and outward from the tarsus of the entire metatarsus.